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Tech Notes

July 1990

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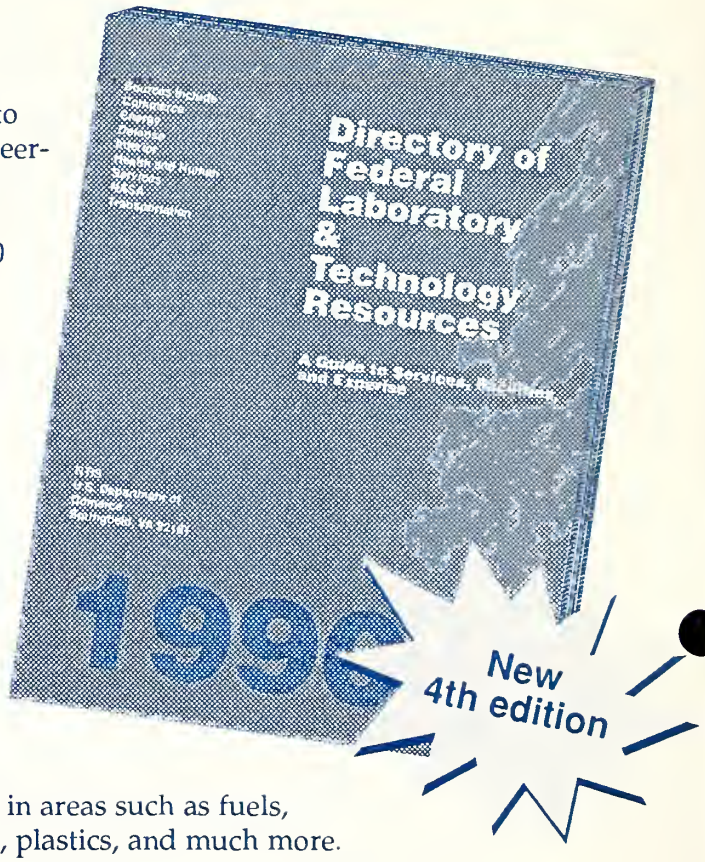

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1990-91 *Directory of Federal Laboratory & Technology Resources—A Guide to Services, Facilities, and Expertise*

Tech Notes

Highlighting Selected U.S. Government Technology & Resources

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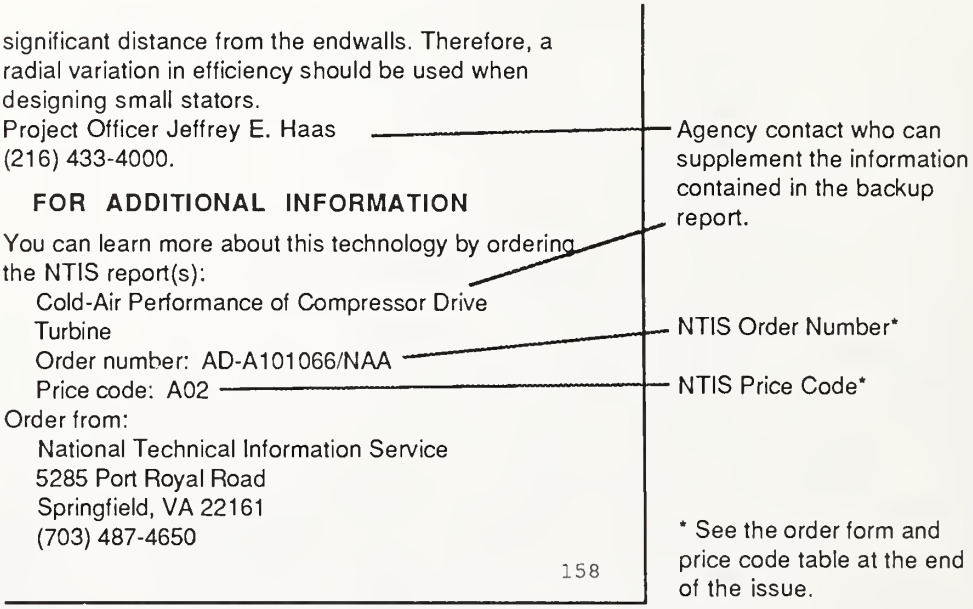
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Project Officer Jeffrey E. Haas
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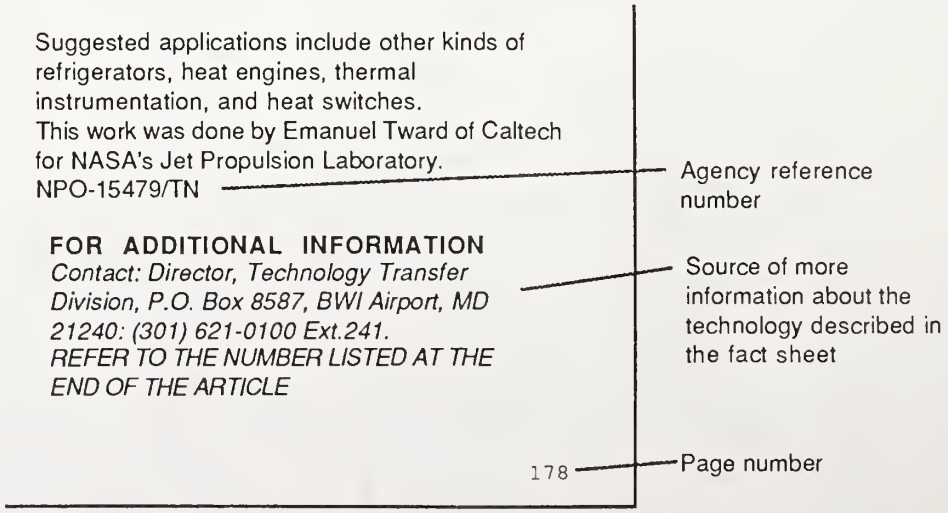
Suggested applications include other kinds of refrigerators, heat engines, thermal instrumentation, and heat switches.
This work was done by Emanuel Tward of Caltech for NASA's Jet Propulsion Laboratory.
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Contact: Director, Technology Transfer Division, P.O. Box 8587, BWI Airport, MD 21240: (301) 621-0100 Ext.241.
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Agriculture & Food

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Research Technology
Agricultural Research Service
U.S. Department of Agriculture

Can Crops Tolerate Acid Rain?

Many farm crops, from lettuce to winter wheat, do not appear to suffer under acid rain, according to research at the ARS Air Quality-Plant Growth and Development Laboratory in Raleigh, North Carolina.

Botanist Denis T. DuBay, plant pathologist Allen S. Heagle, and plant physiologist Walter W. Heck exposed 216 varieties of 18 crops to simulated rain many times more acidic than what now falls in the eastern United States.

The simulated acid rain caused no significant injury, nor did it reduce growth in most species.

Acid rain is precipitation that has picked up airborne pollutants such as sulfur dioxide and nitrogen oxide, which are present in exhaust from factory smokestacks and automobiles.

Such pollutants make rain more acid, decreasing the pH (a logarithmic scale measuring acidity, with pH 7.0 being neutral) to as low as pH 3.0. Rain in North Carolina averages about pH 4.4.

DuBay, Heagle, and Heck first watered their test crops with simulated acid rain at pH 2.5, two orders of magnitude more acid than average rainfall, for a single exposure lasting 1 hour.

"Only in the most sensitive varieties was growth rate reduced," Heck says.

Tomatoes, eggplant, snapbeans, cotton, peanuts, and soybeans were the only crops whose leaves showed damage of more than 5 percent after the 1-hour exposure. The most sensitive variety of tomato had as much as 24 percent of its leaf area damaged by the single exposure.

ROB FLYNN

Botanist Denis Dubay takes a sample of the acid rain solution being tested on soybean plants. Each table top has an open dish to collect the rain mixture for laboratory analysis. (K-3314-1)

Injured leaves had small bleached or burned spots, usually where water droplets had remained on the leaves for an extended time or where a large volume of water had flowed over the surface.

At the other end of the scale, potatoes, corn, lettuce, winter wheat, orchardgrass, melons, fescue, cucumbers, alfalfa, clover, and squash all had less than 2-percent leaf damage, DuBay says.

The researchers also looked at whether chronic exposure to acid rain, for up to 15 days at a time, had an effect.

"We were hoping to find that the results of chronic and acute exposure could be correlated, allowing us to use the much quicker 1-hour

exposure in the future to screen varieties for sensitivity to acid rain," Heck says.

Lettuce, tomatoes, soybeans, and winter wheat were selected for the series of chronic exposures because they were among the most sensitive and the most tolerant crops in the acute tests. As hoped, the two crops most injured in the acute tests, tomato and soybean, also suffered the greatest growth reductions in the chronic tests. Winter wheat and lettuce, the two crops least injured in the acute tests, showed little or no growth reductions.

Leaf damage among tomato varieties at pH 3.0 ranged from a high of 45 percent of the leaves injured for Castlepeel II down to Walter Villemarie 744, with only 5 percent. With soybeans, the damage ranged from 9 percent for Vinton 81 to 24 percent for Corsoy.

"Variation among cultivars means that for susceptible crops, we may be able to breed hardier strains if we need to," Heck says.

But the most significant finding is that pollution danger to crops is more likely to be from sources other than acid rain, Heagle says, sources such as ozone and ultraviolet radiation.

Allen S. Heagle and Walter W. Heck are at the USDA-ARS Air Quality-Plant Growth and Development Laboratory. Denis T. DuBay is with the research faculty, Department of Botany, North Carolina State University. The mailing address for all three is 1509 Varsity Drive, North Carolina State University, Raleigh, NC 27606 (919) 737-3311. ◆

TECHLINE
Microbial and Biochemical Technology

Shiitake Mushroom Cultivation

Shiitake mushrooms are cultivated commercially by inoculating a hardwood log with live fungal cells.

Some of the most underutilized forest materials are small-diameter hardwood trees and the limbs and tops of larger trees. The U.S. inventory of small-diameter hardwoods is increasing due to the lack of suitable outlets. Profitable uses are needed for this material so that selective thinning becomes economically attractive to improve stagnated forest stands.

A promising alternative now emerging in the United States is the conversion of this material into a new high-value forest crop—the edible shiitake (she-ee-ta-kee) mushroom. Shiitake is already the major cultivated mushroom of the eastern hemisphere. Japan alone produces over $1 billion of shiitake annually as one of their leading agricultural exports.

Over the past several years, researchers at the Forest Products Laboratory have been transferring the existing Oriental technology to the United States and studying the cultivation of shiitake on domestic hardwoods (such as oak) and certain agricultural lignocellulosic materials (such as corn cobs).

Shiitake can be cultivated on either small-diameter hardwood logs (2- to 8-inch diameter) or on particulate media, such as hardwood sawdust, with or without the inclusion of other lignocellulosic materials. Yields from logs can be as high as 9 to 35 percent fresh-weight mushrooms per fresh-weight logs over a 3- to 8-year period. Yields from particulate media can be as high as 50 to 140 percent fresh-weight mushrooms per dry-weight medium over a 3- to 9-month period.

The cultivation of shiitake on logs starts with harvesting the trees during winter or early spring and cutting them into convenient-length logs. The shiitake producer then drills openings in the logs and inoculates them with living fungal cells (spawn). He incubates the logs in stacks to allow the fungus to colonize and then restacks the logs for fruiting and harvesting the crop. The colonization and/or fruiting can be done either out-of-doors (traditional method) or indoors (forced-fruiting method). Soaking the logs in water can be used to stimulate fruiting and boost mushroom yields.

Shiitake is cultivated on particulate media in controlled chambers with carefully regulated environments. The media is prepared, sterilized, and inoculated with a suitable fungal strain. The fungus colonizes the media, which typically is kept in plastic bags to keep the cultures free of contaminants. Once colonized, the fungal culture is removed from the containers and the conditions in the growth chamber are changed to ensure mushroom production.

Shiitake mushrooms can also be grown commercially on particulate media such as hardwood sawdust.

Shiitake cultivation is gradually becoming established throughout the United States and is expected to be an excellent growth industry for the next several years. The first shiitake national symposium and trade show was held in May 1989.

For additional information, contact:
Information Group
Forest Products Laboratory
One Gifford Pinchot Drive
Madison, Wisconsin 53705–2398
(608) 231–9200

Computers

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Sandia National Laboratory

Archimedes Enables Robot to Program its Own Plans

A Sandia National Laboratories scientist has developed prototype computer software that for the first time enables a robot to "program itself" to assemble mechanical components.

The new software program, named Archimedes, includes routines by which the system "reasons" which steps are necessary to accomplish a given task. In this way it automatically generates assembly plans and the robotic programs that are needed to carry them out.

The program is the result of interdisciplinary research; hence it was named for the ancient Greek physicist, engineer, and mathematician.

Designed by David R. Strip of Sandia's Computer Sciences Department for use in the U.S. nuclear weapons production complex, Archimedes is believed to have far-reaching implications for design and manufacturing for U.S. industry in general.

Plan satisfies constraints

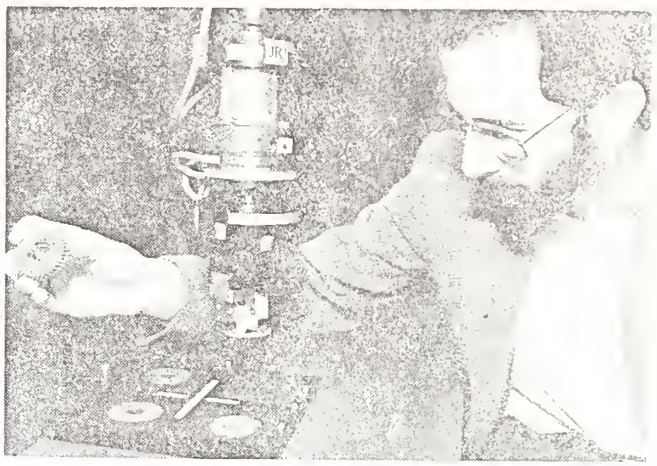
Strip's computer program begins with a three-dimensional Computer Aided Design (CAD) model of a product. From this, a "generic" assembly plan is automatically produced that satisfies the constraints of geometry, stability, and accessibility that were deduced from the model. In the next step, a plan compiler converts the generic plan into robot- and application-specific code.

A working demonstration of the prototype shows how a plan is created for a strong-link pattern wheel—a mechanical coding device designed to ensure the safety of nuclear weapons.

"Robots work well in mass production situations such as painting or welding in the automobile assembly line, where a single task can keep a robot busy for months or years," explains Strip. "However, robotic workcells are often too costly to set up and program for the small batches we see in the weapons production complex."

"By automating the setup and programming of robotic workcells we open new territory for the economical use of robots. This has the potential for a profound effect not just on the weapons production complex, but on manufacturing in general."

Though the concept of getting a robot to automatically program itself is not new, Strip said, no one was successful in doing so in the area of mechanical assembly until now.



Sandia researcher David Strip places parts in a 'parts kit' that a robot (arm shown) picks up and assembles into a strong-link component. The robot uses an assembly that's developed by the Archimedes computer program.

A crucial part of Strip's work was to create routines in which mathematical descriptions of each part are manipulated in three-dimensional space. Within the computer, the spatial relationships of the parts are analyzed to determine how the parts can be brought together and secured in the correct configuration. There are thousands of possible orderings for assembling the parts of the pattern wheel, only a few of which are correct.

Analyzes assembly choices

Typically Archimedes will analyze a number of ways of accomplishing each assembly function, noting which is infeasible (e.g., one part blocking another's path), until it finds a solution. Then it continues to another function until the assembly is complete in the computer. Sometimes the assembly can't be carried out with the robot's single "hand." In these cases, the system will design the necessary fixtures to hold parts during the otherwise infeasible operations.

A compiler takes the assembly plan and develops the instructions that are followed by a specific robot type. The plan can be retargeted to a different robot by making small changes in the compiler.

In Strip's demonstration of the software's capability, a commercially available robot assembles the pattern wheel parts as programmed by the computer sys-

tem. Using computer vision, it determines the locations of the parts, then picks them up one by one and assembles them in their proper positions. Where necessary it exchanges the manipulators needed by its single mechanical arm to pick up the two different kinds of parts—a pneumatic gripper for picking up the pins or a vacuum gripper for picking up the flat cogs—in the sequence determined by the system. It also follows other special instructions issued automatically by the system, for example turning the workpiece to permit welding on the underside.

Pat Eicker, manager of Sandia's robotics group, is enthusiastic for the potential of this kind of program in commercial production applications. "Robots are difficult to program and not many people know how to do it," he says. "They need lots of support because robots just aren't very capable, despite what you might have read."

Strip refers again to the automobile industry as an example of current practice: "If a new car comes along, it's a big deal. The whole robot system has to be manually reprogrammed and reconfigured from the ground up."

In describing the impact on manufacturing, Strip explains that "systems like our prototype can change the relationship between design and manufacturing. An engineer will quickly be able to see the effect of design changes on ease of manufacture. This opens the way for a radical change in how we manufacture goods."

"The ability to quickly and cheaply write robot programs will allow the use of robots in the production of small batches, even one-of-a-kind items," adds Ed Barsis, Sandia's Director of Computer Sciences and Mathematics.

Strip was aided in development of Archimedes by three Sandia colleagues—J. L. Akins, Clifford Loucks, and Colin Selleck of the Intelligent Machines Principles Division.

FOR ADDITIONAL INFORMATION

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Refer to announcement 25, No. 1

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Markov Chains for Testing Redundant Software

The reliability of multiple-version process-control software is verified.

A preliminary design has been developed for a validation experiment (actually, a numerical simulation) that addresses problems unique to assuring the extremely high quality of multiple-version programs in process-control software. In addition, the approach takes into account the inertia of the controlled system in the sense that it can take more than one failure of the control program to cause the controlled system to fail.

The verification procedure consists of two steps: experimentation (that is, numerical simulation) and computation, with a Markov model for each step. The experimental step consists of running the programs through many simulated missions and recording the states of the programs for each iteration of the control loop. The states in the Markov chain represent the number of programs that give correct answers during the current iteration of the control loop, and the transitions are the probabilities of changing states for the next iteration. The estimates of the transition probabilities, together with confidence limits, result from an analysis of these data.

This procedure makes no assumptions about independent failures of the programs. It includes the effect of the operating environment where the next input is a function of external forces (or the mathematical equivalent of forces) and previous control reactions. It captures the possible lingering effect of a previous failure of a program and the possible effect of an input region on such a failure.

The computational step modifies the Markov chain used in the experimental step by adding more states and rearranging some of the transition probabilities. The additional states express the fact that it is necessary for the majority of programs to fail several times in a row before the controlled system is finally made to fail. The values for the transition probabilities are those determined by the experiment, but they occur somewhat differently in the structure of the new chain. The probability of the failure of the system due to faults in the multiple-version software is computed from this modified model.

Although the actual operation is carried out as described, the pre-experimental design phase proceeds in reverse order. An analysis of the second Markov model reflecting the inertia of the controlled system is made to determine what values of transition probability give the required reliability. In general, confidence intervals depend on the number of trials. Because one of the goals is a procedural efficiency greater than that of natural life testing, this number is chosen so that the increase in efficiency is about one order of magnitude.

The most important aspect of this technique is that the approach offers an efficient method for verification of the reliability of multiple-version control software with no assumption of the failures of independent programs. It includes a confidence level and realistically includes the effect of the control environment on the reliabilities of programs.

This work was done by Allan L. White of **Langley Research Center** *and Jon A. Sjogren of the U.S. Army Avionics Research and Development Activity.*
LAR-13812/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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The computational step modifies the Markov chain used in the experimental step by adding more states and rearranging some of the transition probabilities. The additional states express the fact that it is necessary for the majority of programs to fail several times in a row before the controlled system is finally made to fail. The values for the transition probabilities are those determined by the experiment, but they occur somewhat differently in the structure of the new chain. The probability of the failure of the system due to faults in the multiple-version software is computed from this modified model.

Although the actual operation is carried out as described, the pre-experimental design phase proceeds in reverse order. An analysis of the second Markov model reflecting the inertia of the controlled system is made to determine what values of transition probability give the required reliability. In general, confidence intervals depend on the number of trials. Because one of the goals is a procedural efficiency greater than that of natural life testing, this number is chosen so that the increase in efficiency is about one order of magnitude.

The most important aspect of this technique is that the approach offers an efficient method for verification of the reliability of multiple-version control software with no assumption of the failures of independent programs. It includes a confidence level and realistically includes the effect of the control environment on the reliabilities of programs.

This work was done by Allan L. White of **Langley Research Center** *and Jon A. Sjogren of the U.S. Army Avionics Research and Development Activity.*
LAR-13812/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center, Houston, Texas

Portable High-Frequency Data-Acquisition System

A compact unit would be made of readily available solid-state components.

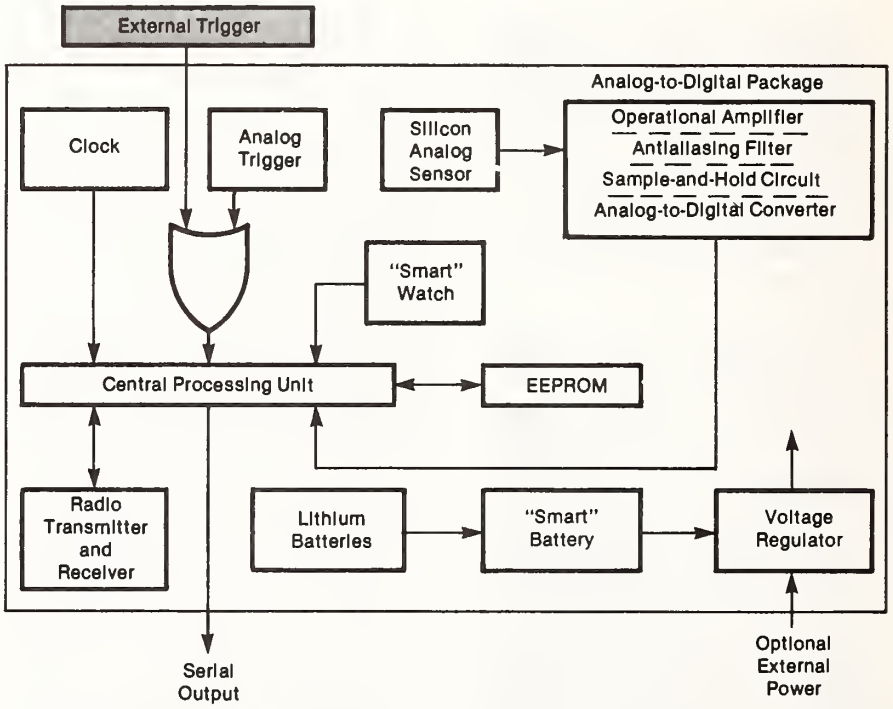
A proposed system for the acquisition of rapidly changing data would be self-contained and portable. The system was conceived for monitoring such aerodynamic effects as flutter, vibration, shock, sound, and pressure. It offers precise and fast acquisition of data and large data-storage capacity: it would have a maximum sampling rate of 125 kHz, an access time of 15 ns, and a 1-million-bit memory.

The system would measure time with a "smart" (microprocessor-controlled) watch that could maintain calendar time for more than 10 years without external power. It would provide standby power from a "smart" battery that could furnish up to 1 ampere-hour of charge if power from the main batteries were lost.

A silicon transducer would send an analog signal representing the dynamic phenomenon being monitored to an integrated analog-to-digital (A/D) package (see figure). There, the signal would first be processed through a low-noise, fast operational amplifier. An antialiasing filter would remove some unwanted noise and eliminate false signals caused by the convolution of the input-signal spectrum with the spectrum of the output pulse train. A sample-and-hold circuit would store brief (2.8-μs) samples of the filtered signal. Finally, an A/D converter would digitize the sample to 12 bits at a rate up to 125 kHz.

An electronically erasable and programmable read-only memory (EEPROM) would store the digitized signal. A central processing unit (CPU) would control the EEPROM as well as retrieval of the stored data through either direct serial electrical output or a radio transmitter.

Lithium batteries or an optional external source would provide power. The "smart" battery would take over if the main lithium batteries or the external source were to fail. The voltages of all power sources would be regulated.



The **Integrated Analog-to-Digital Package** is essential to the conceptual data-acquisition system. A commercial component, the package offers high speed and precision. Data could be retrieved directly through a serial output port or remotely via a radio transmitter.

A clock would synchronize the system and operate an analog trigger, which would start and stop the acquisition of data. Optionally, an external trigger could be used for this purpose. The "smart" watch would keep time in hundredths of seconds, hours, days, months, and years. It would monitor the main power supply and, if it found the voltage going low, would switch to its own lithium battery so that it could keep running.

This work was done by Roy W. Mustain of Rockwell International Corp. for **Johnson Space Center.**
MSC-21521/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Software Model of Software-Development Process

Costs, times, and other quantifiable attributes of development of large computer programs are estimated.

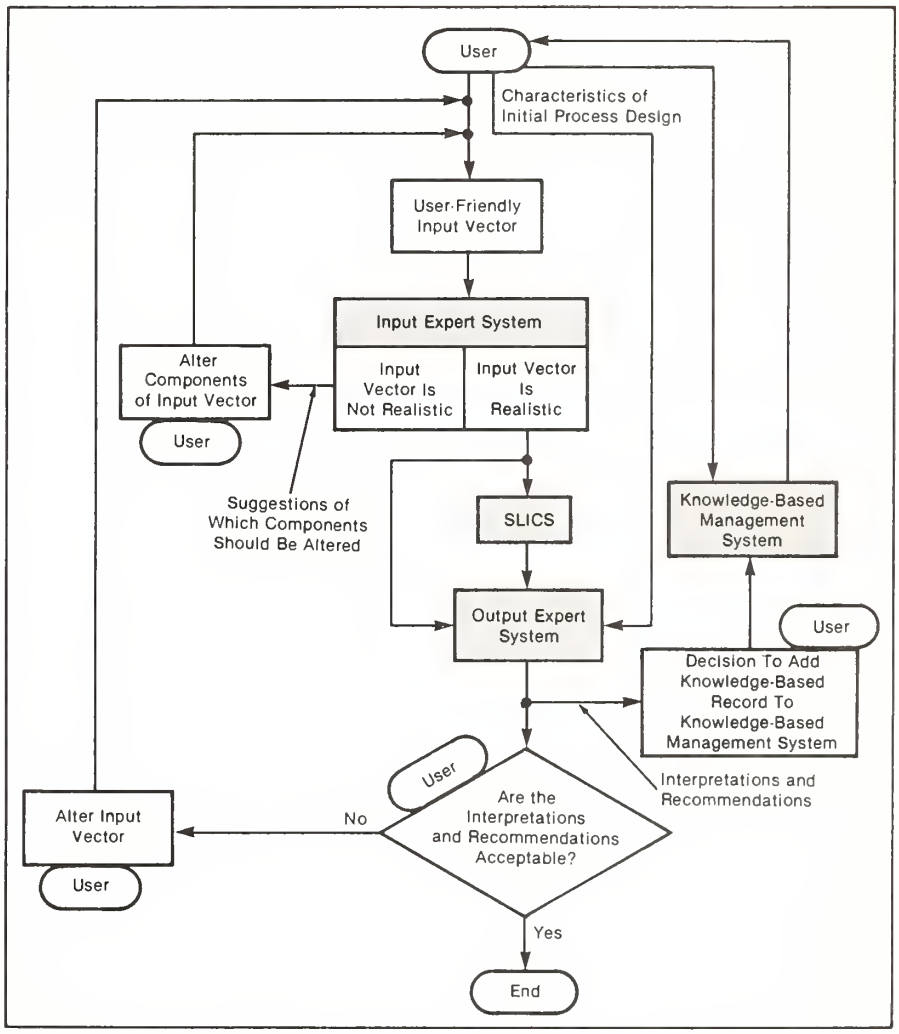
A collection of computer programs constitutes a software tool for the simulation of medium- to large-scale software-development projects. The tool is intended to aid managers in planning, managing, and controlling software-development processes by reducing the uncertainties in budgets, required personnel, and schedules.

To make an adequate mathematical model of a complicated development process, it is necessary to quantify characteristics that are usually difficult to quantify and/or identify, like human factors and feedback loops. Of course, it is also necessary to include easily identifiable and more-readily quantifiable characteristics like costs, times, and numbers of errors. A mathematical model that incorporates these and other factors of the dynamics of the software-development process is implemented in the Software Life Cycle Simulator (SLICS) computer program.

SLICS is composed primarily of staff, product, and budget subsystems. The staff subsystem models the functions that determine the required level of the work force. The product subsystem models the functions that describe progress in developing the software product. These functions are determined by the productivity and the rework activities that are needed when requirements are changed or errors are detected.

The budget subsystem includes functions that model various expenditures and the total cost in relation to the available budget. The budget subsystem controls both the staff and the product subsystems according to the status of the budget. The staff and product subsystems are linked through information on the assignment of personnel and through the status of progress toward the completed product.

SLICS is integrated with an input expert system, an output expert system, and a knowledge-based management system, to obtain the overall software collection called the Hybrid Expert Simulation System (HESS) for software-development processes (see figure). The input expert system (IES) verifies the compatibility of the components of the input vector. The IES alerts the user to any erroneous input vectors before the vectors are inserted into SLICS. The IES also makes recommendations as to which components of the input vector should be altered.



SLICS simulates the dynamics of a software-development process. In combination with input and output expert software systems and a knowledge-based management software system, it develops information for use in managing a large software-development project.

The output expert system makes recommendations regarding the software-development process, based on analysis of the output from SLICS, the characteristics of the input vector, and, if applicable, the characteristics of the initial design of the software-development process undergoing simulation. The output expert system also suggests how to alter the input vector to make the recommendations more desirable.

The knowledge-based management system is a data-based management system composed of knowledge-based records. Each knowledge-based record is composed of a vector of input data (i.e., input vector) and its respective set of recommendations. After each simulation run, the user decides whether to add the resulting knowledge-based record to the knowl-

edge-based management system.

In combination with the other programs in HESS, SLICS can be used for any or all of the following:

- To test various management actions, policies, options, and procedures;
- To test the impacts of various assumptions, scenarios, and environmental factors on the software-development process;
- To predict the consequences of management actions on the interrelationships among components and flows of the software-development process; and
- To examine the sensitivity of the software-development process to various internal and external factors.

This work was done by Chi Y. Lin and Debra J. Synott of Caltech and Reuven R. Levary of St. Louis University for **NASA's Jet Propulsion Laboratory.** *NPO-17424/TN*

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NIST Technology Update
National Institute of Standards & Technology
U.S. Department of Commerce, Gaithersburg, MD 20899

Upgraded Program Aids Police Vehicle Selection

Police patrol vehicles are bought by the tens of thousands yearly in this country, but choosing the right vehicle for individual department needs can be a dilemma. Now, police fleet managers seeking economy and appropriate features can use the latest version of AutoBid, a computer software program that grades potential fleet acquisitions on a variety of performance parameters. The program incorporates test scores published annually by the Michigan State Police Department on the dynamics, accelerations, speed, braking, ergonomics, and fuel economy of vehicles on the market. It helps users combine these scores with bid prices to determine the lowest cost for needed performance. Developed at NIST, AutoBid (Version 2.0) is the first major upgrade to the original NIST-created AutoBid program now used in over 450 police departments. The upgrade has new features such as bargraph displays, printed vehicle score data sheets, vehicle hardware comparisons, and access to data from several vehicle model years. Autobid runs on most personal computers and can be used directly from a floppy drive or may be installed on a hard drive. Free copies of AutoBid are available to interested police departments from the Law Enforcement Standards Laboratory, NIST, B116 Polymer Bldg., Gaithersburg, Md. 20899; telephone: 301/975-2757. Supplies are limited. Autobid was developed for the National Institute of Justice as part of its Technology Assessment Program.

FOR ADDITIONAL INFORMATION: Law Enforcement Standards Laboratory, NIST, B116 Polymer Bldg., Gaithersburg, Md. 20899; 301/975-2757.

Electrotechnology

0550 Anomalous Polarization May Improve Infrared Detectors—New configurations are proposed for quantum-well devices.

0551 Asymmetric Memory Circuit Would Resist Soft Errors—Some nonlinear error-correcting codes are more efficient in the presence of asymmetry. (Licensing Opportunity)

0552 Balanced-Bridge Feedback Control of Motor—Sensitivity to variations in electrical and mechanical characteristics would be reduced.

0553 Concept for Generation of Long Pseudorandom Sequences—A VLSI design would be based on exponentiation in a finite field.

0554 Digital Demodulator for Advanced Receiver—Complexity and cost are reduced by a new design for half-band filters. (Licensing Opportunity)

0555 Disturbance-Accommodating Controller Would Aim Antenna—Existing methods of control are combined to suppress systematic errors.

Software

0556 Analyzing Optical Communication Links—Link margins and design-control tables are generated from input parameters supplied by the user.

Testing & Instrumentation

0557 Tester Detects Steady-Short or Intermittent-Open Circuits—Momentary open circuits or steady short circuits trigger a buzzer.

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

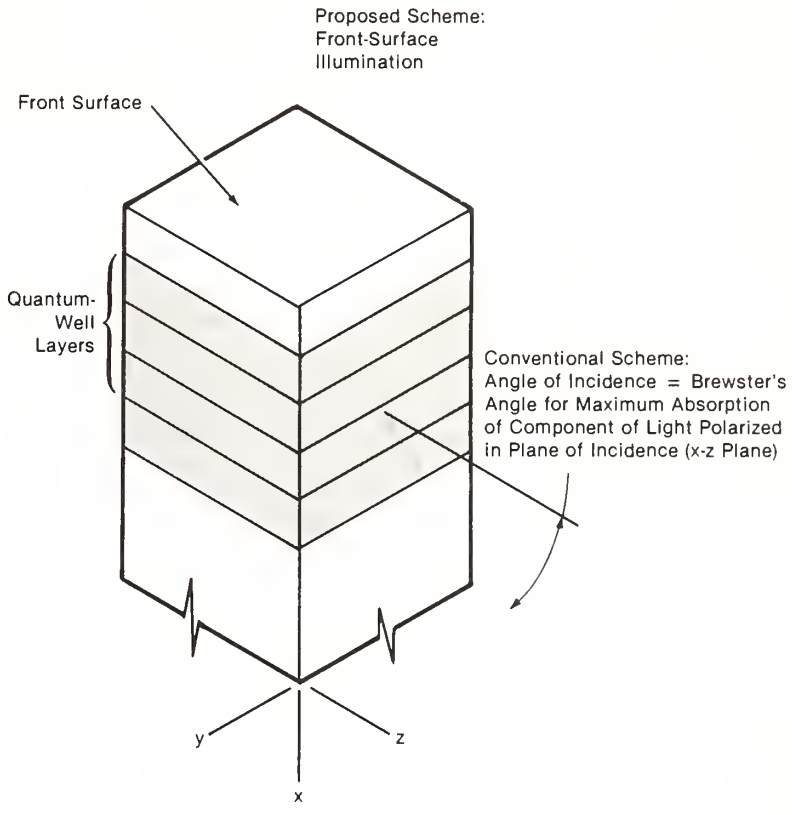
Anomalous Polarization May Improve Infrared Detectors

New configurations are proposed for quantum-well devices.

An anisotropic quantum effect that has been overlooked until now may simplify the alignment, increase the sensitivity, and open up more possibilities in the design of quantum-well detectors of infrared radiation. Heretofore, it has been thought necessary to illuminate such a device at Brewster's angle (see figure) to maximize the absorption of light by channeling, into the waveguide structures defined by the quantum-well planes, as much as possible of the component of incident radiation that is polarized perpendicularly to these planes. However, a device made according to the newer concept could be illuminated directly on its front side; no special waveguide structures would be required.

The behavior of a quantum-well device can be analyzed via the effective-mass approximation. Such an analysis shows that if the device material has an isotropic effective mass, then the component of incident radiation polarized in the quantum-well plane (*y-z* plane) does not induce a transition of an electron between different subband energy states; that is, the transition is quantum-mechanically forbidden. Thus, radiation incident along the *x* axis or otherwise polarized in the *y-z* plane is not absorbed and no photocurrent is generated. To effect a transition in the isotropic device, the radiation must have a component polarized along the *x* axis, and this gives rise to the need for the Brewster's-angle/waveguide scheme.

The planes of the quantum wells are perpendicular to the direction of growth (*x* axis). The quantum theory shows that if the material has an anisotropic effective-mass tensor and if the direction of growth is not a principal crystalline axis of the device material, then nonzero off-diagonal (*xy* and *yz*) matrix elements arise between subband energy states, even when the light is incident along the *x* axis (polarized in the *x-z* plane). These matrix elements represent an anomalous polarization effect that causes the absorption of light incident along the *x* axis.



In a **Quantum-Well Detector** made according to current practice, the edges of the quantum-well layers should be illuminated at Brewster's angle to maximize the absorption of light polarized in the plane of incidence. In a detector made according to the proposed concept, light incident broadside on the front surface would be absorbed.

This effect can be exploited to increase the sensitivity of an infrared detector by illuminating the front surface broadside (light incident along the *x* axis) to take advantage of its large surface area, which can be of the order of 1 cm^2. The sensitivity of a device could be maximized by the choice of suitable material and by orientation of the crystalline axes along directions that maximize the anomalous polarization effect.

This work was done by Chan-Lon Yang of Caltech and Dee-Son Pan of UCLA for **NASA's Jet Propulsion Laboratory**. *NPO-17450/TN*

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Asymmetric Memory Circuit Would Resist Soft Errors

Some nonlinear error-correcting codes are more efficient in the presence of asymmetry.

A combination of circuit-design and coding concepts is expected to make integrated-circuit random-access memories more resistant to "soft" errors (temporary bit errors, also called "single-event upsets" due to ionizing radiation). An integrated circuit of the new type would be made deliberately more susceptible to one kind of bit error than to the other, and the associated error-correcting code would be adapted to exploit this asymmetry in error probabilities.

A random-access memory can be regarded as a communication channel with a long delay, in which the writing and reading operations correspond to transmitting and receiving, respectively. In a binary symmetric communication channel, the probability of an erroneous transition from 0 to 1 equals the probability of an erroneous transition from 1 to 0. Linear error-correcting codes for binary symmetric channels are well developed; such codes can be applied to data written into symmetric random-access memories, and decoding and error correction can take place during the subsequent reading operation. The error-correcting capability of such a code increases with the apportionment of more bits within fixed-length code words as parity-check bits. Thus, as the error-correcting ability increases, less information can be stored and retrieved, and vice versa.

In a random-access-memory cell, the probability P(01) or P(10) of an erroneous zero-to-one or one-to-zero transition, respectively, can be increased by enlarging those circuit elements that are more susceptible to one of these types of error (see figure). Nonlinear group-theoretical error-correcting codes can be adapted to exploit the asymmetry of an ideal binary asymmetric channel, in which only one kind of erroneous transition occurs [e.g., P(10) = 0]. In practice, it is not necessary to have an ideal binary asymmetric channel as long as the ratio of transition probabilities is sufficiently large [e.g., P(01)/P(10) > the length of a codeword] and as long as the greater transition probability [in this example P(01)] is less than one-half.

For a given fixed codeword length and error-correcting capability, the number of distinct code words in a group-theoretical code for a binary asymmetric channel often exceeds the number of code words in a code for a binary symmetric channel. Equivalently, for the same codeword length and error-correcting ability, a binary asymmetric channel can carry more bits of data — or use less overhead. In an error-correcting asymmetric random-access memory based on this concept, the proportion of an integrated-circuit chip devoted to the correction of errors can thus be made smaller than in a symmetric version. Alternatively, for the same error-correcting proportion, the error-correcting capability of the asymmetric version can be greater.

This work was done by Martin G. Buehler and Marvin Perlman of Caltech for **NASA's Jet Propulsion Laboratory.**

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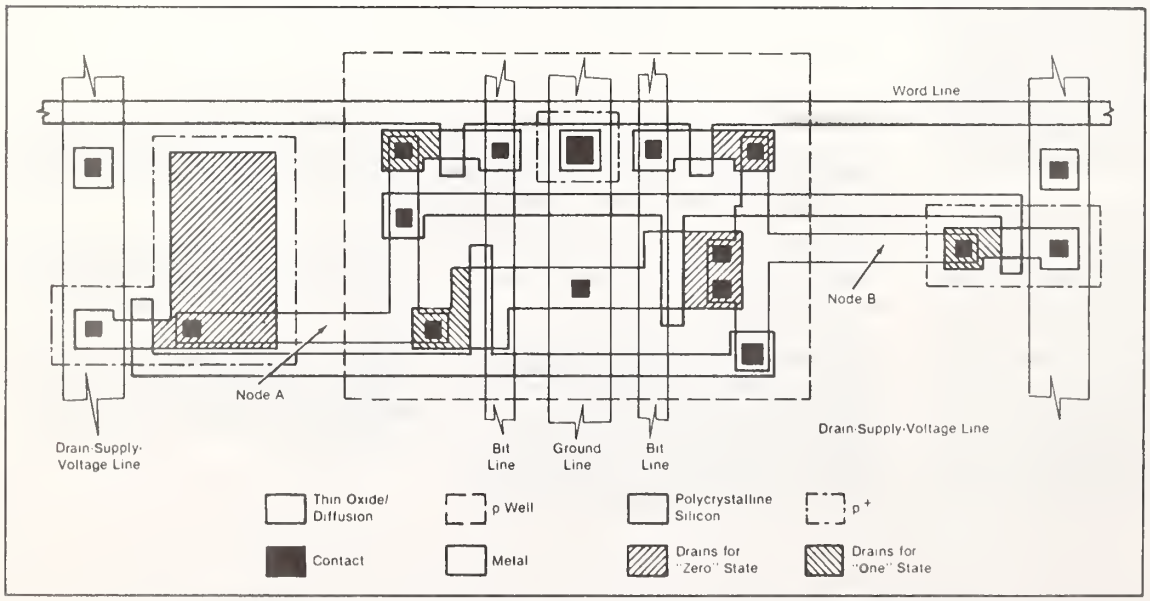

The Drains of a Random-Access-Memory Cell that are susceptible to single-event upsets are indicated by crosshatching. Those for the "zero" state are greater than those for the "one" state. Thus, erroneous zero-to-one transitions are more probable than are erroneous one-to-zero transitions in this circuit.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

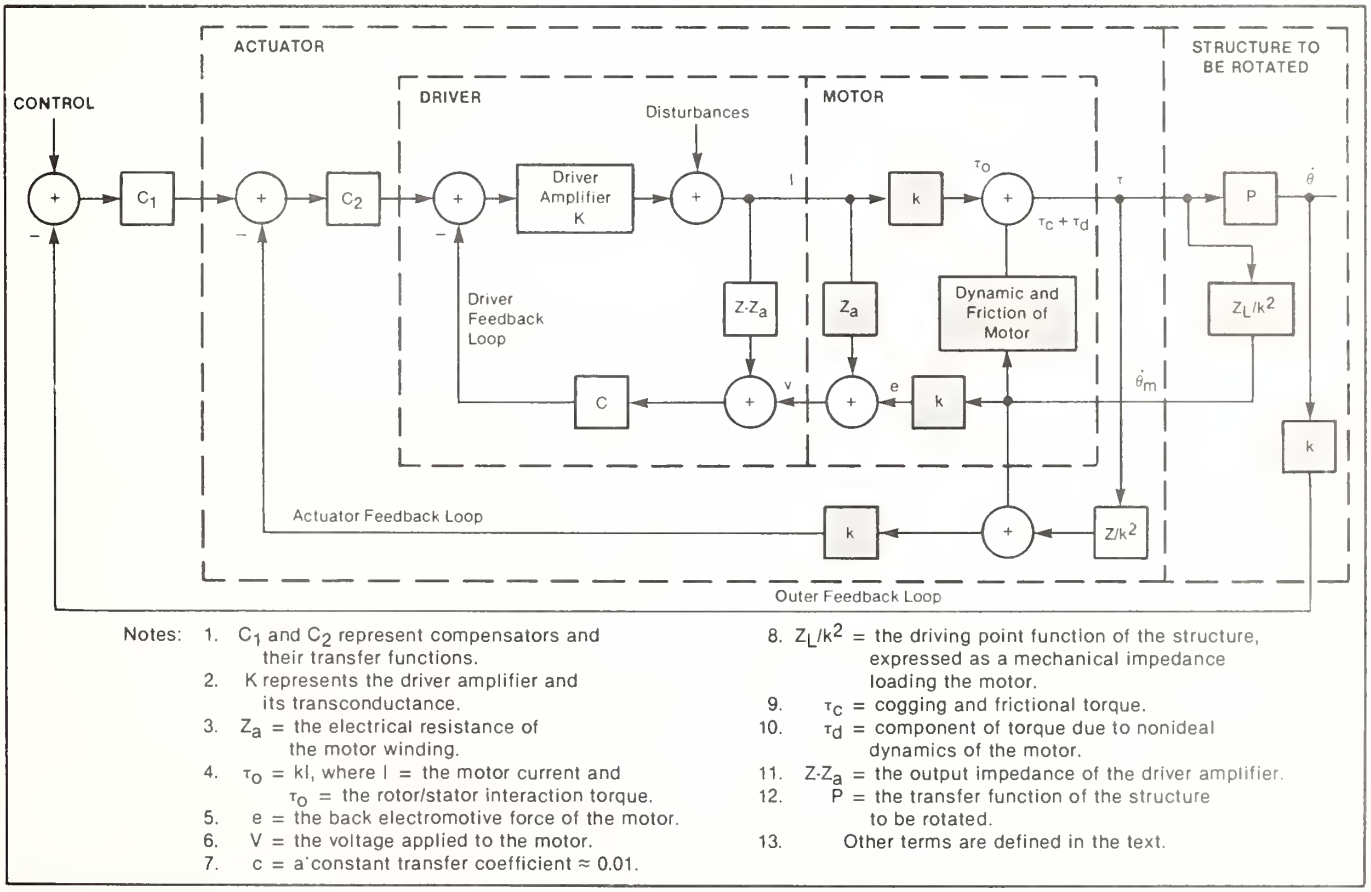
Balanced-Bridge Feedback Control of Motor

Sensitivity to variations in electrical and mechanical characteristics would be reduced.

A proposed control system for a motor-driven rotary actuator would include three nested feedback loops, which, when properly designed, would be decoupled from each other. The system is intended to increase the accuracy of control by mitigating such degrading effects as vibrations and variations in the electrical and mechanical characteristics of the structure to be rotated. The system lends itself to the optimization of performance via the independent optimization of each of the three loops.

The conceptual system includes outer, actuator, and driver feedback loops, configured so that the actuator is a subsystem, and the driver is a subsystem of the actuator (see figure). The torque τ exerted by the motor on the structure is sensed and used as a component of actuator feedback. The angular speed $\dot{\theta}_m$ of the motor shaft relative to the stator and the angular speed $\dot{\theta}$ of the structure in the inertial space are also sensed and used in the actuator and outer feedback loops, respectively.

Current and voltage feedback in the



Notes:
1. C_1 and C_2 represent compensators and their transfer functions.
2. K represents the driver amplifier and its transconductance.
3. Z_a = the electrical resistance of the motor winding.
4. τ_o = kI, where I = the motor current and τ_o = the rotor/stator interaction torque.
5. e = the back electromotive force of the motor.
6. V = the voltage applied to the motor.
7. c = a constant transfer coefficient ≈ 0.01.
8. Z_L/k^2 = the driving point function of the structure, expressed as a mechanical impedance loading the motor.
9. τ_c = cogging and frictional torque.
10. τ_d = component of torque due to nonideal dynamics of the motor.
11. $Z \cdot Z_a$ = the output impedance of the driver amplifier.
12. P = the transfer function of the structure to be rotated.
13. Other terms are defined in the text.

The Feedback Control System includes three nested loops that can be optimized independently of each other to reduce the susceptibility of the overall system to vibrations in the structure and variations of mechanical and electrical characteristics.

driver loop are chosen to be proportional correspondingly to the torque and $\dot{\theta}_m$ feedback in the actuator loop to obtain a "balanced-bridge" configuration This makes it possible to reduce the sensitivity of the overall closed-loop system to variations in the characteristics of the structure by transferring the effects of uncertainty in the structure from the actuator loop to the driver loop. As a consequence, the gain of the actuator loop can be increased without adversely affecting its stability, thereby reducing significantly the effects of the disturbances that originate in the actuator. Also, the margins of stability of the actuator loop are relatively independent of the characteristics of the structure.

The balanced-bridge configuration also reduces the effects of friction in the motor on the stability of the outer feedback loop. Consequently, the feedback gain of this loop can also be increased to reduce the effects of disturbances that originate there. The flexibility in the choice of the output impedance of the driver can be exploited to improve the overall performance and to reduce further the sensitivity of the outer loop to variations in the parameters of the structure.

This work was done by Boris J. Lurie of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-17430/TN.

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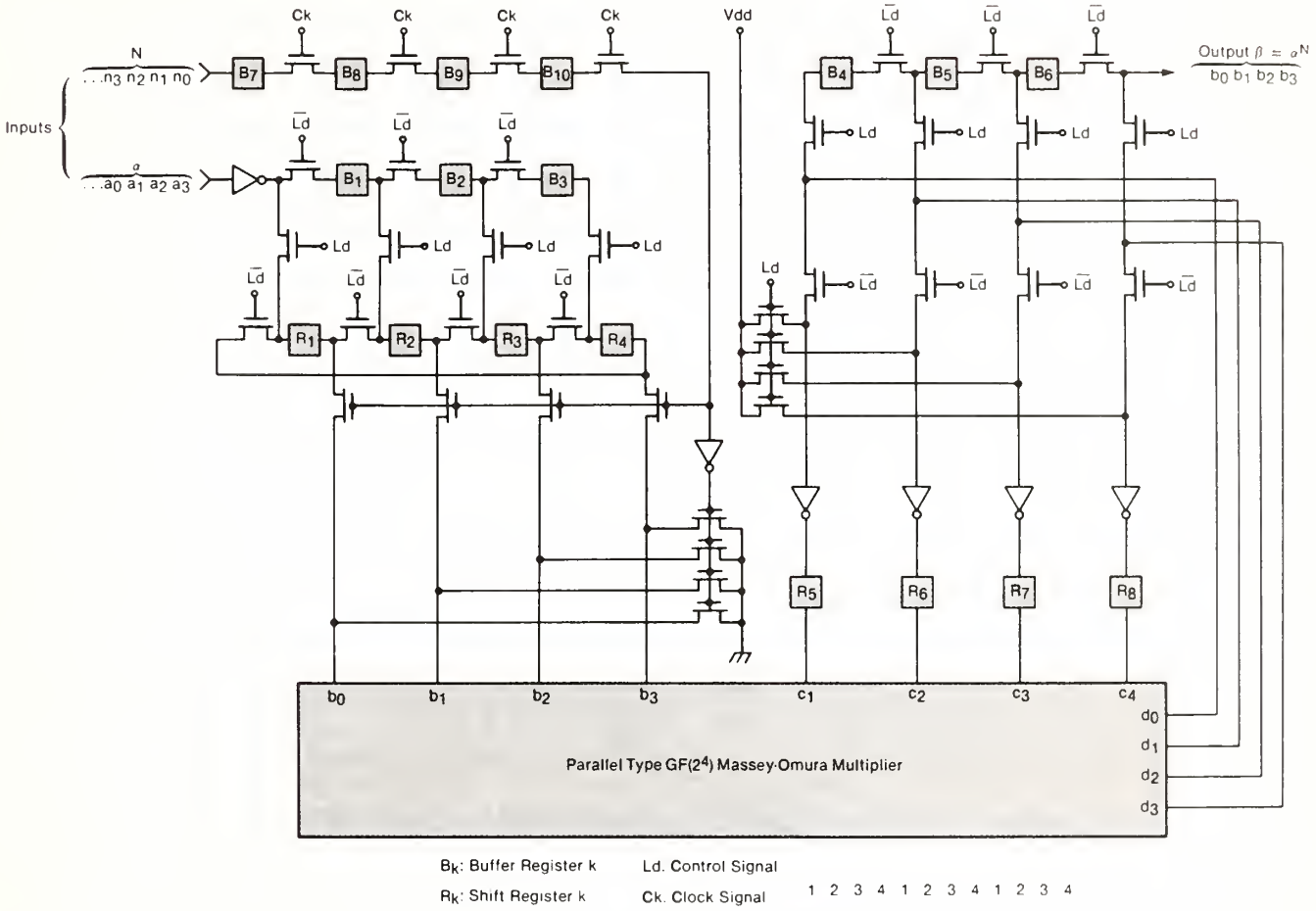
NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Concept for Generation of Long Pseudorandom Sequences

A VLSI design would be based on exponentiation in a finite field.



This Circuit Computes Exponentials $\beta = \alpha^N$ in the finite field $GF(2^4)$, where N ranges from 1 to 15. The circuit operates in a "pipeline" manner: each computation requires four clock cycles, during which the bits of the previously computed β are shifted out and the bits of the following α are fed in.

A conceptual very-large-scale integrated (VLSI) digital circuit would perform exponentiation in a finite field. An algorithm that generates unusually long sequences of pseudorandom numbers would be executed by a digital processor that includes such circuits. The new concepts are particularly advantageous for such applications as spread-spectrum communications, cryptography, and the generation of ranging codes, synthetic noise, and test data, where it is usually desirable to make pseudorandom sequences as long as possible.

A previously-developed modular VLSI multiple-tap pseudorandom-sequence generator is composed of n stages of shift register and generates a periodic sequence with period $2^n - 1$. The sequence produced by that circuit is believed to have a maximum length for linear algorithms of n stages. Like the maximal-length shift register, the new system requires n shift registers, but it also requires exponentiation in finite fields and yields a much longer period. Although the new sequences may not have flat spectra as do the sequences generated by the maximum-length shift register, the increase of the period is very desirable in some applications.

The first problem is to calculate the exponential $\beta = \alpha^N$, where α is in the finite field $GF(2^m)$ and $1 \leqslant N \leqslant 2^m - 1$. The solution is obtained by successive multiplications according to a recursive algorithm executed by the combination of a cyclic-shift circuit, a parallel-type Massey-Omura multiplier, and a control-logic circuit (see figure).

It can be shown that if A_0 is a primitive element in $GF(2^m)$, and if $\{E_k\}$ is a sequence of $2^n - 1$ distinct numbers (where

$n \leq m$), which are less than 2^n, then the sequence of exponentials $A_k = A_o^{Ek}$ in $GF(2^m)$ represents a sequence of pseudorandom numbers that repeats with a period of $2^n - 1$. A random-number sequence can also be generated from

$$A_k = A_0^{p^s \prod_{i=1}^{t} E_i}$$

where $p = (2^n - 1)! \bmod (2^m - 1)$, $k = s(2^n - 1) + t$, and $n < m$. If $2^m - 1$ is a Mersenne prime, then the period of $\{A_k\}$ is increased to $(2^n - 1)r$, where r is an integer that satisfies several other criteria. In general, this period is much greater than that of a sequence generated by a maximal-length shift register of an equivalent number of stages. For example, with $m = 19$ and $n = 17$, the period is 34,359,345,153, which is 262,143 times the period 131,071 generated by a 17-stage shift register.

This work was done by C.C. Wang of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17241/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Digital Demodulator for Advanced Receiver

Complexity and cost are reduced by a new design for half-band filters.

A digital demodulator has been designed for use in the reception of phase- and amplitude-modulated digital signals of bandwidths up to 15 MHz on microwave carriers. The system performs coherent demodulation in phase and in quadrature with the carrier locked in phase to an intermediate frequency of 10 MHz. In statistical simulations and in tests of a "breadboard" version, the demodulator exhibited the expected high performance at low signal-to-noise ratios. The design is suitable for fabrication in very-large-scale integrated circuitry.

The intermediate frequency is digitized to 8 bits at a sampling rate of 39.6 MHz (chosen to avoid interference that would occur at 40 MHz). The demodulator multiplies the samples by cosine and sine waveforms at the 10-MHz intermediate frequency, thereby generating the in-phase and quadrature baseband signals, plus the sum-frequency components (see Figure 1).

The principal innovative feature of the demodulator is the design of the half-band digital low-pass filters that remove the sum-frequency components. In concept, this kind of filter is a special case of the class of low-pass finite-impulse-response (FIR) filters of order *N*. The half-band concept was chosen partly because almost half of the *N* filter coefficients are zero, and consequently, the number of multiplications and additions required is only half that of an arbitrary linear-phase digital filter. This reduces the required complexity of the circuitry, particularly when decimation by 2 is used.

Other considerations that favor this selection include the following:

- The width of the stopband equals the width of the passband. This is ideal for the elimination of sum frequencies that cause complex heterodyning, because the sum-frequency components have the same bandwidth as that of the difference-frequency components to be passed.
- The peak deviations of the ripples in the passband and the stopband are equal. As a result, the signal-to-noise ratio due to the passband ripple is about the same as that due to the sum-frequency noise aliased into the passband after decimation by 2.

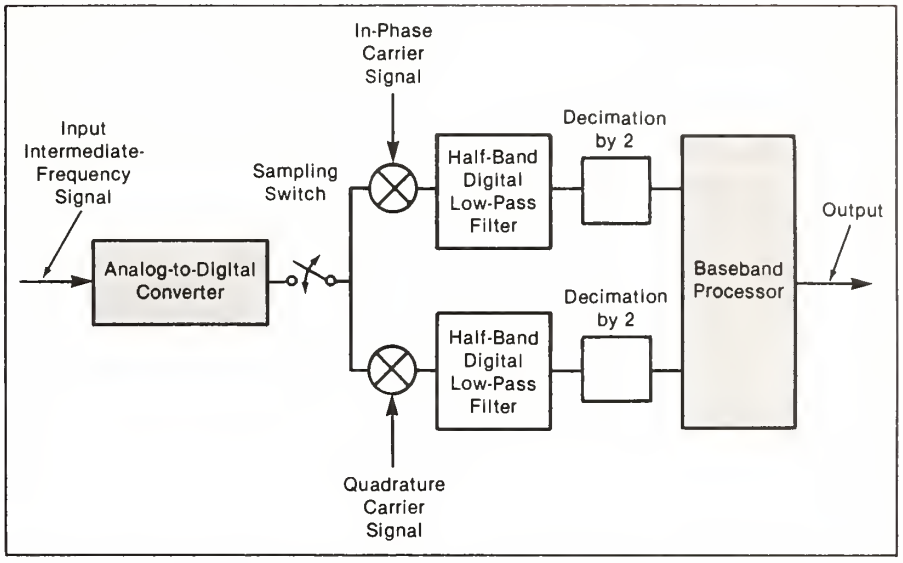

Figure 1. The **Digital Demodulator** performs coherent demodulation on the in-phase and quadrature components.

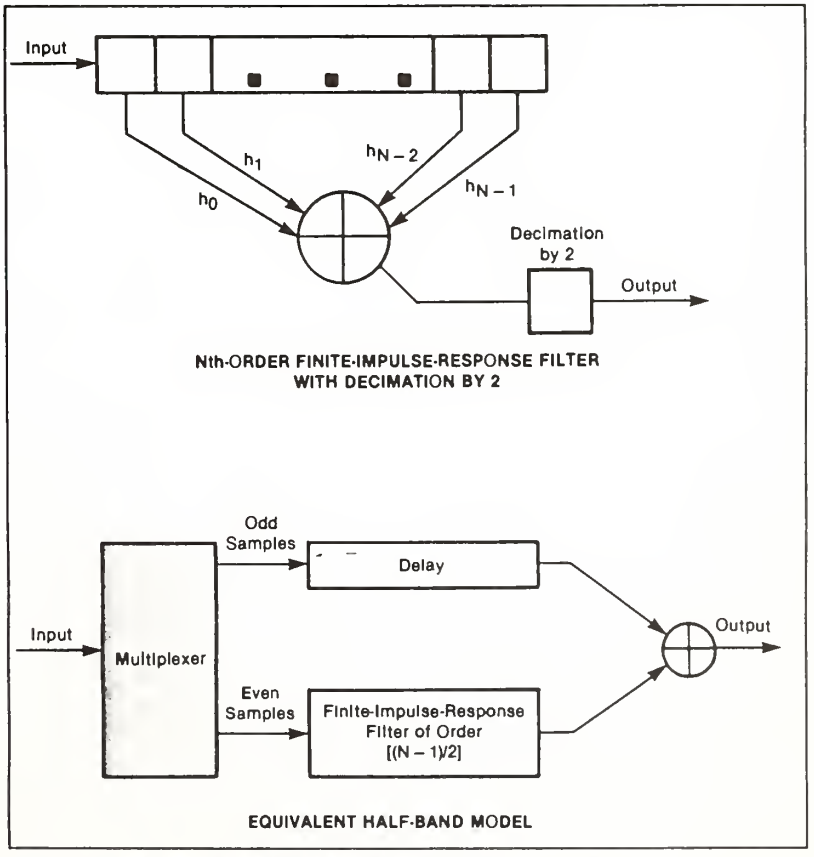

Figure 2. The **Half-Band Digital Low-Pass Filters** of Figure 1 are a special case of *N*th-order finite-impulse-response filters suitable for decimation by 2.

- When a decimation factor of 2 is employed, the processing rate is also reduced by a factor of 2.

Figure 2 illustrates a simplified architecture for the Nth (N odd) order half-band finite-impulse-response filter. The output y_n of the filter at the nth sampling interval is given by

$$y_n = \sum_{j=-[(N-1)/2]}^{j=[(N-1)/2]} h_j x_{n-j} + x_n$$

where j is odd and x_k denotes the input at the kth sampling interval.

In this expression for y_n with even n (decimation factor of 2), the only term in the output that involves the even samples is the last term, which corresponds to the center tap of the filter. Thus, it is possible to reduce the computation of y_n for even n into a lower-order (half) filtering and an addition operation. First, the input is demultiplexed into odd and even samples. The odd samples are filtered by an $[(N+1)/2]$-tap finite-impulse-response filter. The output of the filter is summed with the delayed even sample. The simplicity of this architecture is evident in the comparison with structure of the general fast-impulse-response filter. The length of the delay (in sampling periods) in the simplified model is $(N+1)/2 + \tau$, where τ is the pipeline delay through the fast-impulse-response filter.

This structure has the important additional advantage that the filter operates at half the input frequency. Thus, the components can be slower than those of a general finite-impulse-response filter. This helps to reduce the cost. It also enables building the filter to operate at twice the speed of available multipliers or FIR filter circuits. Furthermore, it is also possible to take advantage of the symmetry of the coefficients of the fast-impulse-response filter to reduce the number of multiplications by another factor of 2.

This work was done by Ramin Sadr and William J. Hurd of Caltech for **NASA's Jet Propulsion Laboratory**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-17628/TN.

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FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

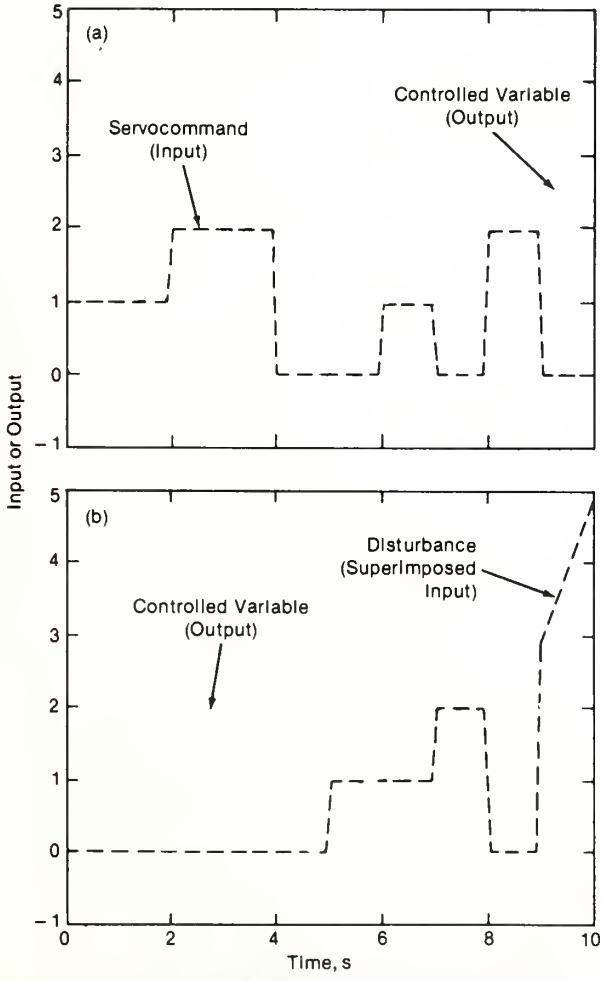
Disturbance-Accommodating Controller Would Aim Antenna

Existing methods of control are combined to suppress systematic errors.

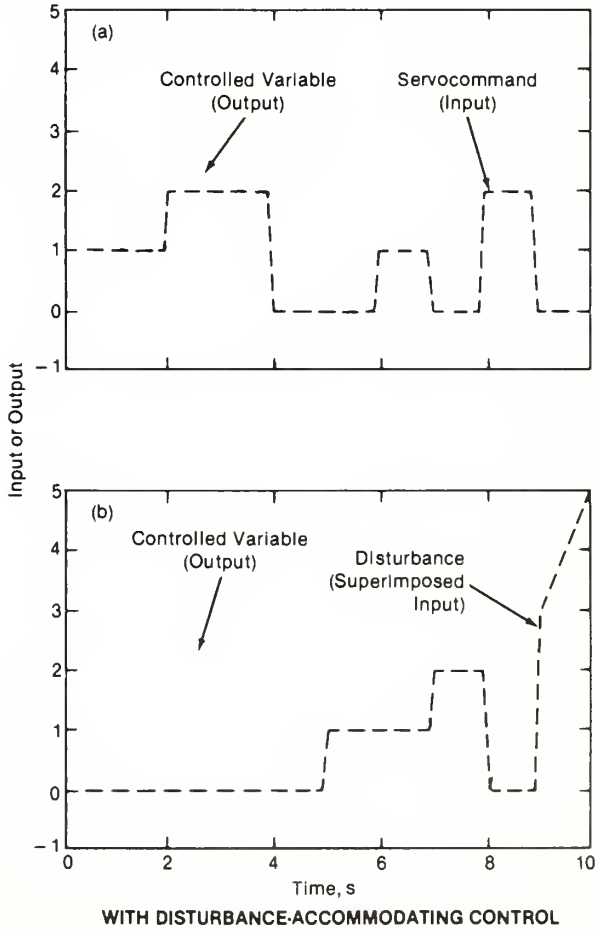
A proposed system for aiming a large paraboloidal-dish antenna is based on the theory of disturbance-accommodating control. The new concept of control incorporates features from previously developed concepts to suppress systematic errors caused by misalignment of the antenna, sensor noise, and random thermal and wind disturbances.

Errors in the aiming of antennas in pointing and tracking are typically functions of static and dynamic factors. Mechanical misalignments of sensors or inaccuracies in the predictions can be considered as static factors, whereas dynamic factors would include wind, thermal, and gravitational loading. The approach here is to cancel the static errors for precise pointing of the antenna by treating the systematic misalignment errors, as well as the servocommands, as disturbances to the controlled system.

Aiming can be improved through a sequence of modifications solely in existing software. Current algorithms can be enhanced to provide simultaneously servotracking and correction of the systematic errors as well as stabilization of beams in the presence of random disturbance torques. For a given antenna, servodrive, feed, and distortion of the surface, a software package could be developed to optimize the performance to achieve, adapt-



WITHOUT DISTURBANCE-ACCOMMODATING CONTROL



WITH DISTURBANCE-ACCOMMODATING CONTROL
(OUTPUT FOLLOWS ONLY THE SERVOCOMMAND INPUT)

The **Servocommand Responses** of a single-variable system with discrete-time digital control were simulated numerically. The disturbance in the output is clearly suppressed when disturbance-accommodating control is included.

ively, the maximum antenna gain for a prescribed direction vector with a "smart" controller.

A typical antenna controller includes an analog velocity-control loop and a position-control loop closed through a digital computer. The algorithms for the control of position are either proportional-integral (PI) or state feedback control algorithms. The PI control involves the application of gains to the position error and the integral of position error. The weighted sum of these signals is the commanded rate for the velocity-control loop. This type of control system results in zero steady-state error when the input is a ramp signal.

The more sophisticated method utilizing state feedback allows specification of the eigenvalues of the closed position-control loop. The initial disadvantage of state feedback is the requirement that all the states of the system be available for the feedback control. The technique of estimation of the state has circumvented this problem, providing the controller with an estimate for each of the unmeasurable or uncertain state signals. The feedback gains are selected to yield the designer's selected eigenvalues to achieve the desired performance of the system.

In the proposed disturbance-accommodating controller, another vector would be estimated simultaneously with the estimation of the state vector. This other vector would represent the disturbance state, which could then be used in determining a more-complete control strategy.

The disturbance-accommodating controller is designed to synthesize and reject the waveformlike disturbances that are encountered in practice in tracking systems for antennas. The disturbances can be mathematically modeled according to a priori data by determination of the corresponding differential equation and, hence, the representation of the state of the waveform-structured noise.

The results of a computer simulation show that the disturbance-accommodating controller can cancel systematic errors, while simultaneously allowing an optimal-control policy to regulate the system (see figure). The disturbance-accommodating controller is easy to implement along with the existing servocontrol. Such practical issues as the order of the mathematical model, computation time, and storage requirements offer no expected challenges in the design of microprocessor-based controllers.

This work was done by L.L. Gresham, F.L. Lansing, and C.N. Guiar of Caltech for **NASA's Jet Propulsion Laboratory**. *NPO-17631/TN*

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Analyzing Optical Communication Links

Link margins and design-control tables are generated from input parameters supplied by the user.

The Optical Communication Link Analysis Program, OPTI, analyzes optical and near-infrared communication links that use pulse-position modulation (PPM) and direct detection. The program prompts for inputs of parameters of components of a system, modulation format and other parameters of operation, sources of background noise, and the desired bit-error rate of the link. From these inputs, the link margin is determined, and a link design-control table (DCT) is generated. The program also enables the user to save sets of input parameters that define a given link and read them back into the program later. Further, the program can alter automatically any of the input parameters to achieve a desired link margin.

In computing the link margin, the program calculates the received optical signal power, background power, and required signal for the desired level of performance (error rate). Background sources are taken from a list of extended sources (e.g., planets, the Moon, and the Sun) and point sources (stars) contained within the program and from additional sources specified by the user. In the case of additional sources, the user must specify the irradiance (for point sources) or radiance and distance from the source to the receiver (for extended sources). Objects within the program are treated as blackbodies at an appropriate temperature with an overall magnitude scaled to match tabulated data.

The OPTI program is written in FORTRAN 77 and was designed to be used on the IBM PC and PC/AT personal computers. (Note: The 8087/80287 math-coprocessor option is highly recommended for use with this program.) The program will also compile under UNIX 4.3 BSD FORTRAN 77 with minor changes.

This program was written by William K. Marshall and Brian D. Burk of Caltech for **NASA's Jet Propulsion Laboratory**.

NPO-17444 /TN

FOR ADDITIONAL INFORMATION

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Athens, GA 30602
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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Tester Detects Steady-Short or Intermittent-Open Circuits

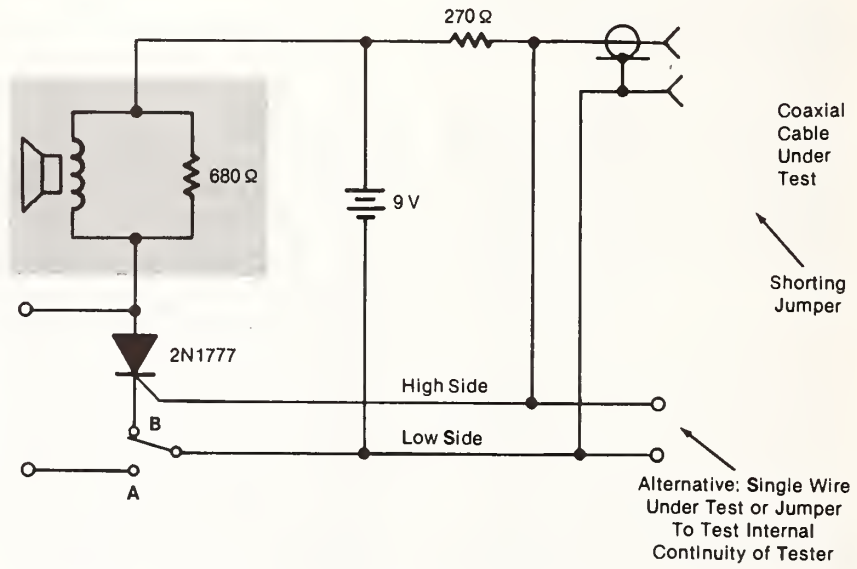
Momentary open circuits or steady short circuits trigger a buzzer.

A simple, portable, lightweight testing circuit sounds a long-duration alarm when it detects a steady short circuit or a momentary open circuit in a coaxial cable or other two-conductor transmission line. The tester is sensitive to discontinuities that last 10 μs or longer. Previously, there was no simple, portable instrument to detect momentary shorts or discontinuities. Such conventional instruments as ohmmeters and lamp- or buzzer-type continuity checkers give visible or audible indications of steady open or closed circuits only.

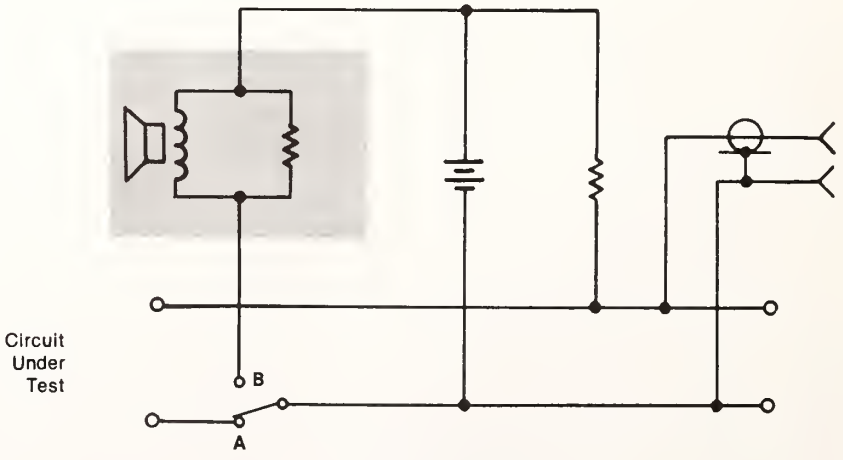
To detect an intermittent open circuit in a coaxial cable, the far end of the cable is shorted by a jumper, and the tester is connected as shown in the upper portion of the figure, with the switch in position B. If the cable is in good condition, the high-side terminal remains grounded, the silicon controlled rectifier remains off, and the buzzer does not sound. If an opening occurs in the center conductor or shield of the coaxial cable, the current from the high-side terminal to the low-side terminal that would otherwise be shunted by the cable flows into and triggers the silicon controlled rectifier and thereby turns on the buzzer. Even if the coaxial cable starts to conduct again, the buzzer remains on until the silicon controlled rectifier is reset by turning the switch to position A. An intermittent discontinuity in a single wire (or an internal discontinuity in the tester) can be detected in this manner if no coaxial cable is connected and the wire or jumper is connected as shown in dashed lines.

To detect a steady short circuit, the jumper is removed. If the buzzer does not sound, there is a steady short circuit between the inner and outer conductors. If the buzzer does sound, then the cable is either good or open.

The tester is used extensively for detecting intermittent open shorts in accelerometer and extensometer cables. The tester can also be used as an ordinary buzzer-type continuity checker to detect steady short or open circuits. For this purpose, the switch is set at position A and the probe leads are connected as shown by dashed lines in the lower portion of the figure. In this case, the silicon controlled rectifier is not part of the circuit, and the buzzer remains on only so long as the circuit under test provides a conducting path.



DETECTION OF INTERMITTENT DISCONTINUITIES OR STEADY SHORTS



CONTINUITY BUZZER

The **Tester Detects Intermittent Discontinuities** (above) or shorts (below, right connections). It can also be used as an ordinary continuity buzzer (below, left connections).

This work was done by Bobby L. Anderson of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29466/TN

Energy

0558 Destroying Toxic Wastes

0559 Peak Detecting Fast Charger For Nickel-Cadmium Batteries

Technology Application

Solar Energy Research Institute

Destroying Toxic Wastes

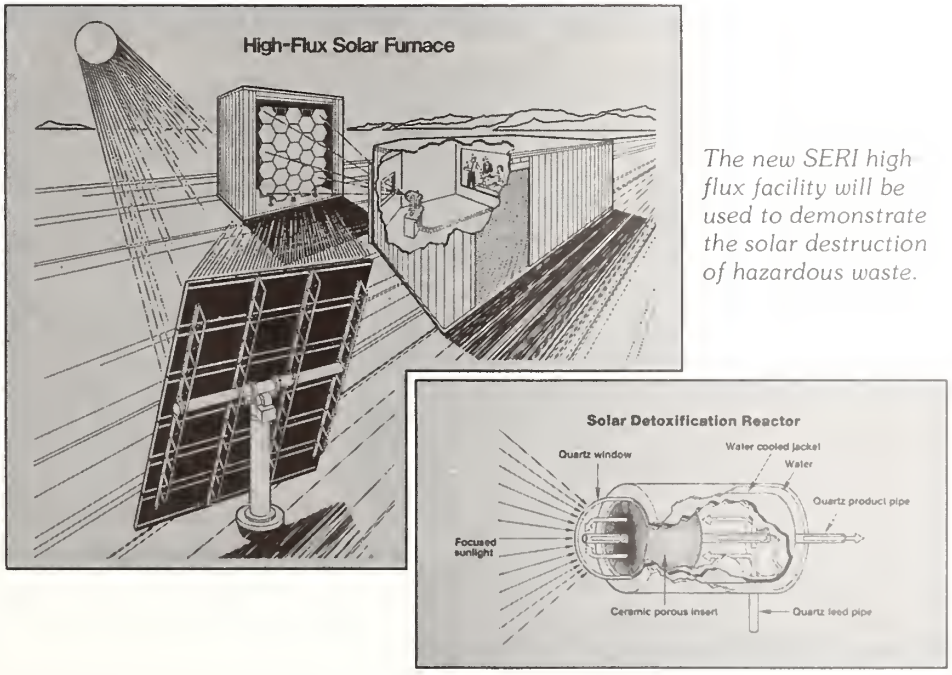
SERI researchers are taking advantage of the way light interacts with matter to destroy toxic wastes such as dioxins and pesticides. Their solar thermal process uses highly concentrated sunlight to convert toxins to nonhazardous by-products. It operates at lower temperatures and produces less carbon dioxide than conventional incineration techniques.

Using experimental reactors with the solar furnaces at Sandia National Laboratories and the White Sands Missile Range in New Mexico, SERI researchers have destroyed dioxin beyond detection limits—well beyond the stringent 99.9999% efficiency required by the Environmental Protection Agency (EPA). Test results were verified using certified EPA methods.

High destruction efficiencies were also achieved for two common industrial solvents, trichloroethylene and methylene chloride.

Destruction occurs in a reactor at the focus of a parabolic dish or central receiver, where wastes are bombarded by a beam of sunlight concentrated 500-1000 times and heated to temperatures of 750-1000°C. Low-energy photons in the infrared and visible portions of the spectrum heat the waste. Then high-energy photons in the ultraviolet region help to break the chemical bonds and destroy the molecules. Use of high-energy photons has another benefit: Process temperatures can be reduced by as much as 400°C below those required for conventional incineration, leading to significant energy savings.

SERI has also sponsored tests at the University of Dayton Research Institute, where scientists used a 2-kW solar simulator to destroy dioxins, polychlorinated biphenyls (PCBs), and chlorinated and



The new SERI high flux facility will be used to demonstrate the solar destruction of hazardous waste.

halogenated hydrocarbons.

With a new research facility now under construction, SERI will be better equipped to study these and other applications of high-temperature, high-flux solar radiation. Researchers plan to assess possibilities for contaminated soil cleanup, in which concentrated sunlight would be used to remove toxins and then break them down into nonhazardous gases and acids, and on-site destruction of certain industrial waste streams.

For Additional Information:

John Anderson
Solar Energy Research Institute
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Golden, CO 80401-3393
(303) 231-1022

Refer to Volume XI, Number 3/TN

Technology Application

Fermi National Accelerator Laboratory

Peak Detecting Fast Charger For Nickel-Cadmium Batteries

Nickel-cadmium batteries, for reasons both economic and environmental, are at their best as a reusable resource. Many nickle-cadmium batteries can be fast charged at a high current rate of up to about four times capacity. Peak charging of nickle-cadmium batteries results in the highest level charge possible, leading to maximum battery service. However, peak charging, especially at high current rates is not ordinarily used, since even a slight overcharging can result in excessive battery heat and resultant venting.

A technology for peak charging of nickle-cadmium batteries that solves these problems has been developed at Fermilab. At Fermilab, in-use evaluation has shown that the Peak Detecting Fast Charger (PDFC) reduces previous charging times from 15 hours to 15 minutes.

The simple technology and readily available components of the PDFC make fast peak charging a potential low-cost option for many applications, such as pagers, field radios, clock battery backup circuits, portable celluar radios, cordless tools, and the hobby market. Circuitry diagrams can be obtained by writing to the Laboratory.

FOR ADDITIONAL INFORMATION: Office of Research and Technology Applications, Fermi National Accelerator Laboratory, P.O. Box 500, MS 208, Batavia, IL 60510; (312)840-3333. Refer to FAA-513/TN.

Engineering

0560 Gas-Turbine Expert System

0561 Computer Evaluation of Coal Cutting With Rotary Drum Miners Helps Operators Identify Machine-Dust Relationships

0562 Directional Sprays Reduce Auger Mining Dust Levels

0563 Effective Operation of Conveyor Belt Cleaning Systems

0564 Timber Bridge Program

0565 Wood-Frame House Construction

0566 Combining Thermal and Structural Analyses—A computer code makes programs compatible so that stresses and deformations can be calculated.

0567 Connecting Multiple Wires to a Single Through Hole—A solder cup would make it easier to rework printed-circuit boards.

0568 Electrostatic Linear Actuator—Electrically charged helices would attract or repel each other.

0569 Hot Wax Sweeps Debris From Narrow Passages—Loose particles are removed from inaccessible places.

0570 Measuring Diameters of Large Vessels—A computerized apparatus produces accurate results quickly. (Licensing Opportunity)

0571 Numerical Analysis of Flows With FIDAP—Predictions of FIDAP are compared with other numerical results and with data from experiments.

0572 Perspectives on Dilution Jet Mixing—A study identifies effects of flow and geometric parameters on mixing of transverse jets with ducted crossflow.

0573 Post Clamp With Attached Collar—The collar makes adjustment of optical components easier and faster. (Licensing Opportunity)

0574 Robot Hand Would Adapt to Contours—A conceptual device would use hydraulic pressure to activate fingers.

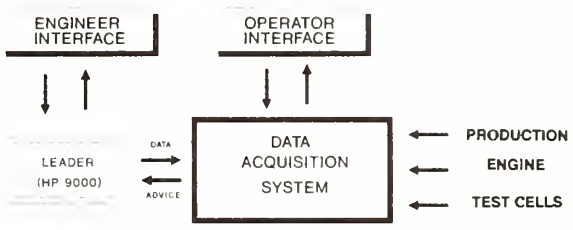
0575 Stowable Mechanical Sound Suppressor—A drive-and-link assembly actuates a system aft of the variable nozzle of an engine.

Technology Fact Sheet
U.S. Air Force

Gas-Turbine Expert System

SYNOPSIS

Knowledge-based systems (KBS), sometimes called Expert Systems, are used to encode human knowledge about a specific task or domain into a computer system. KBS technology goes beyond conventional computer programming techniques in its ability to incorporate knowledge gained from experience in the form of rules. Like humans, Expert Systems use rules of thumb (heuristics), analogies, and logic to reach a conclusion. A knowledge-based system mimics the reasoning of performance of less experienced personnel in performing a task.



TEXTRON LYCOMING PROPRIETARY SYSTEM

The Lycoming Expert Advisor for Diagnostics and Engine Repair (LEADER) has been in operation at the Stratford Army Engine Plant since March of 1988. LEADER is an Expert System that assists test technicians to perform adjustments required to tune the AFT1500 engine used in the M.1 tank. This task was previously accomplished only by engineers with experience in adjusting the power turbine stators in a manner that determines the maximum "open-point" for an individual engine to bring it within test specifications. This procedure requires the evaluation of combinations of parameters measured, or calculated during engine operation. These parameters include compressor speeds, fuel and air flow, temperatures, and torque. Eight different relationships are used by engineers to determine the correct setting of the "open-point". By capturing the knowledge of an expert engineer and encoding it into a software program, test technicians have 24-hour access to assistance required to accomplish this task in the absence of actual engineering support.

LEADER operates without user input, taking all required data from the existing data acquisition system. The adjustment recommendations are provided by the system in a manner which is transparent to the engine test technicians. When an adjustment is required, the Expert System analyzes the data and passes the recommendation to the data acquisition system for display in the existing test system message monitor.

The system consists of the S.1 expert shell, a data reduction program written in FORTRAN, and integration software written in the C programming language. LEADER runs on an HP 9000 computer under Hewlett Packard's version of the UNIX operating system. The Expert System is linked to Textron Lycoming's production engine test data acquisition system via a local area network (LAN) and is transparent to the operator. An overview diagram of the system and its interface with the data acquisition system is illustrated on the previous page. This interface is designed to have no impact on the data acquisition system, should the Expert System computer fail.

APPLICATIONS

Fielded: AGT1500 Engine (M1 Tank)

AIR FORCE R&M 2000 GOAL HIGHLIGHTS

Decrease Manpower Requirements: 24-hour on-line capability reduces the number of engineers required in the test facilities.

Decrease Costs: Annual cost savings of $90,000 (est.) per year.

Increase Combat Capability: Cut the amount of time the engine spent in the test cell by 45 percent and reduced the number of unsuccessful engine adjustments by 67 percent which enhanced the combat readiness of the weapon system.

BENEFITS/DRAWBACKS

A major benefit of this application of an expert system is on-line access, 24 hours each day, providing support equivalent to around-the-clock engineering staff in the test facilities. The expert system has maintained 90 percent accuracy in its adjustment recommendations. Most adjustments can now be performed in less than 5 minutes. Prior to the system's installation, some adjustment trials continued for as long as 2 hours in the absence of engineering assistance.

Although some adjustments still require actual engineering support, there has been a 43 percent decline in the number of adjustments required through the reduction of unsuccessful adjustment attempts.

This expert system is specific to the AGT1500 engine with its unique variable power turbine stators. However, this system demonstrates a successful integration of expert systems technology with an existing data acquisition system in an engine test facility.

DOCUMENTATION

SAE Aerotech 88 Report ISSN 0148-719/88/1003-1443

LEADER - Lycoming Expert Advisor for Diagnostics and Engine Repair. An Expert System which assists test technicians in the performance of engine adjustments on the AFT1500, M.1 Tank.

HEURISTICS - Involving or serving as an aid to learning, discovery, or problem solving by experimental and especially trial-and-error methods. (WEBSTER Dictionary, 1985)

TECHNOLOGY CONTACTS

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This TechTIP report was produced as part of the Technology Transfusion Opportunities Program at the Air Force Office for Logistics Technology Applications (AFOLTA). Determining the feasibility of using this Technology in a particular application requires a thorough evaluation of system requirements and the capabilities provided by the technology. For further information on the subject technology, please contact the listed organizations. Comments or questions about the Technology Transfusion Opportunities Program are welcomed and should be addressed to AFOLTA, Wright Patterson AFB, OH 45433-5000 or call AUTOVON 785-1606, Commercial (513) 255-1606.

New Technology from the Bureau of Mines

U.S. Department of the Interior Bureau of Mines

Computer Evaluation of Coal Cutting With Rotary Drum Miners Helps Operators Identify Machine-Dust Relationships

Objective

Provide mine operators with means for evaluating dust generation and bit wear effects on production without costly and extensive underground testing.

Approach

Develop personal-computer-based cutting system models (CSM's) that will simultaneously evaluate machine, coal seam, and mine-operator-controlled parameters for their interactive effects on dust generation, bit wear, and production by either a longwall shearer or a continuous miner.

How It Works

CSM programs have been developed to analyze relative dust generated by a double-drum, ranging arm, longwall shearer and a continuous miner. These interactive programs provide relative dust, cutting forces, and production values for any given set of mining machine parameters, specific seam conditions, and operator-controllable parameters. Expanded versions of each program provide a dynamic evaluation of the effects of bit wear, over time, on production.

The programs are menu driven, which allows the user to make parametric changes in a minimum of steps. The menus, which control the program flow, allow the user to calculate relative dust values, change parameters, save modified data files, and obtain printed copies of summary reports, lists of modifications, and a listing of the entire data file. Both programs have "Help" menus that provide the user with on-line assistance and descriptions of each of the parameters available.

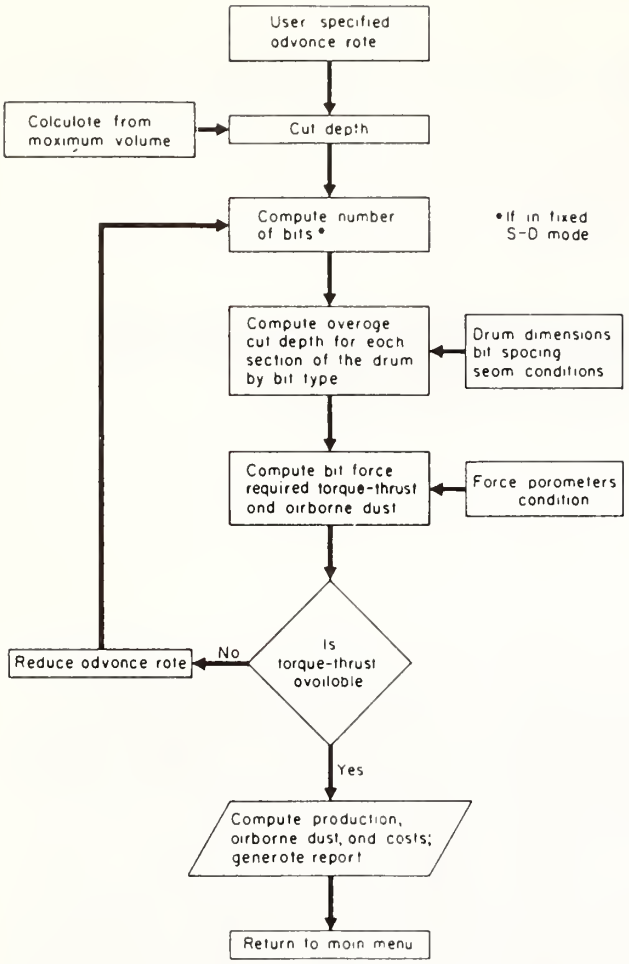
The longwall shearer program uses 60 parameters for a full evaluation of the cutting action and the continuous miner program uses 62 parameters. Each program has a default data file for initial use. Operators using either program will need to spend a few minutes modifying some of these parameters to set up the program to their specific mining conditions. These modifications can be saved to a new data file by following the menu instructions.

The programs provide operators with the option of looking at proposed changes in the cutting system before the system is shut down. With these programs an operator can evaluate, in advance, the potential effect of any change, saving actual machine down time and production loss. The programs have each been tested against field data to validate the techniques used. Excellent correlation has been found between the models and field test data.

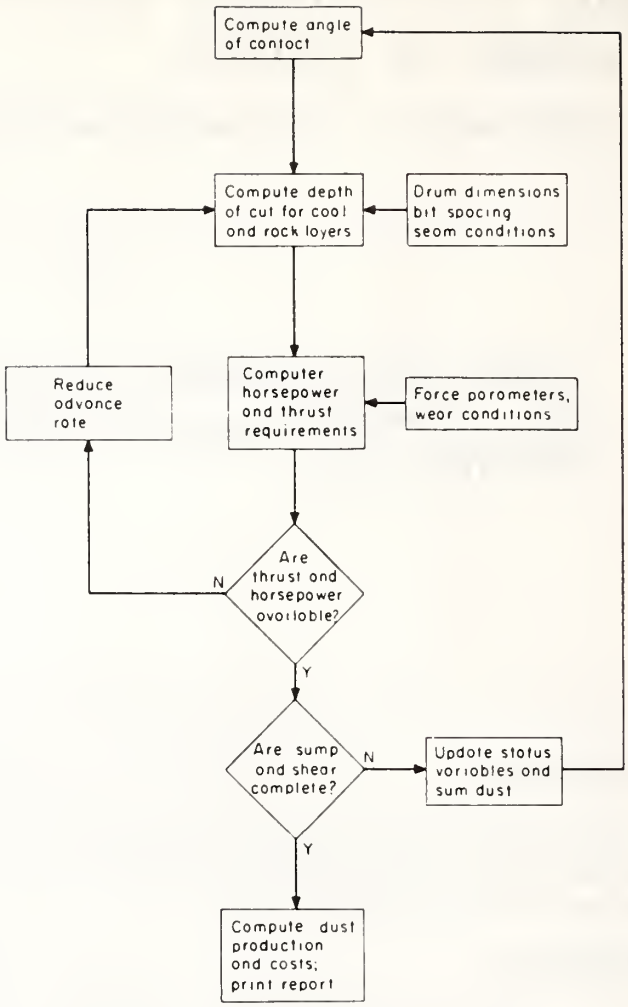
Although the programs, written in BASIC, will run on any IBM XT or equivalent using the Microsoft disk operating system, an IBM AT or equivalent is recommended for the expanded dynamic versions to reduce the running time.

For More Information

A full description of the computer programs, including operation and use, plus a complete program listing for


User specified advance rate
Calculate from maximum volume
Cut depth
Compute number of bits*
*If in fixed S-D mode
Compute average cut depth for each section of the drum by bit type
Drum dimensions bit spacing seam conditions
Compute bit force required torque-thrust and airborne dust
Force parameters condition
Is torque-thrust available
No
Reduce advance rate
Yes
Compute production, airborne dust, and costs; generate report
Return to main menu

Program flowchart for longwall shearer cutting system model.


Compute angle of contact
Compute depth of cut for coal and rock layers
Drum dimensions bit spacing seam conditions
Reduce advance rate
Compute horsepower and thrust requirements
Force parameters, wear conditions
Are thrust and horsepower available?
N
Y
Are sump and shear complete?
N
Update status variables and sum dust
Y
Compute dust production and costs; print report

Program flowchart for continuous miner cutting system model.

*U.S. Government Printing Office: 1989-711-138

both programs, is given in U.S. Bureau of Mines Reports of Investigations (RI's) 9203, "Computer Modeling of Dust and Forces for Longwall Mining Systems," and 9245, "Computer Modeling of Continuous Miner Cutting Systems for Dust Generation." For a free single copy of these RI's, write to the Bureau's Publications Distribution Section, Bldg. 149, P.O. Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

Additional information and technical support may be obtained by contacting the principal investigator:

Bruce D. Hanson
U.S. Bureau of Mines
Twin Cities Research Center
5629 Minnehaha Avenue South
Minneapolis, MN 55417-3099
(612-725-4782)

New Technology from the Bureau of Mines

U.S. Department of the Interior Bureau of Mines

Directional Sprays Reduce Auger Mining Dust Levels

Objective

Reduce dust at the auger mine face by modifying airflow patterns around the mining machine.

Approach

Limited clearance between an auger miner and the mine roof restricts airflow across the face and causes dust rollback. Directional sprays are used to direct air across the face, thereby reducing dust rollback and increasing dust dilution (fig. 1). Laboratory and underground studies were used to test and optimize effectiveness of the directional sprays.

Results of Laboratory Study

Laboratory experiments were conducted in a simulated auger gallery equipped with a full-scale mock auger miner and bridge conveyor. A dual curtain configuration was used to direct the ventilation, which averaged 2,700 cfm throughout the experiment. Testing variables included spray location, pressure, spacing, orientation, and number.

Figure 2 shows the optimized directional spray system, also called the auger clearer spray system. The system consists of three sprays mounted along the intake side of the miner. Sprays are spaced 16 to 24 inches apart, and angled 30° toward the return side of the miner. The 24-inch spacing moved about 7% more air across the face than the 16-inch spacing; however, it resulted in some additional misting on the return side of the miner. A 30° orientation was more effective than a 60° orientation for moving air across the face and minimizing misting on the return side of the miner. Flat fan sprays are used because their spray paths are not obstructed by the top of the miner and mine roof. A 50° fan angle is used to minimize misting on the intake side of the miner.

Increasing the spray pressure from 100 to 200 psi increased airflow by about 30%. Thus, spray pressure should be maintained as close to 200 psi as possible. At 200 psi, a 0.043-inch nozzle orifice diameter (see spray nozzle manufacturer's specifications) is used to limit water use to 2 gpm. This 2-gpm use represents only about 15% of the total water used on most auger miner sections. During laboratory testing, the quantity of air sweeping the face was tripled by increasing the velocity from 70 to 210 fpm; however, such increases may not be obtained outside the laboratory.

Underground Evaluation

An underground dust survey was conducted to determine the dust control effectiveness of the auger clearer. Some modifications were necessary. The mine used a spray pressure of 150 psi instead of 200 psi because hose failures occurred at the higher pressure. Sprays were spaced 24 inches apart because no workers were used on

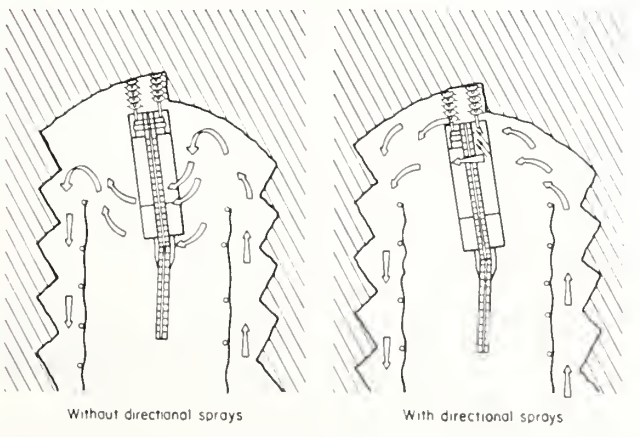


Figure 1.–Airflow patterns at the face.

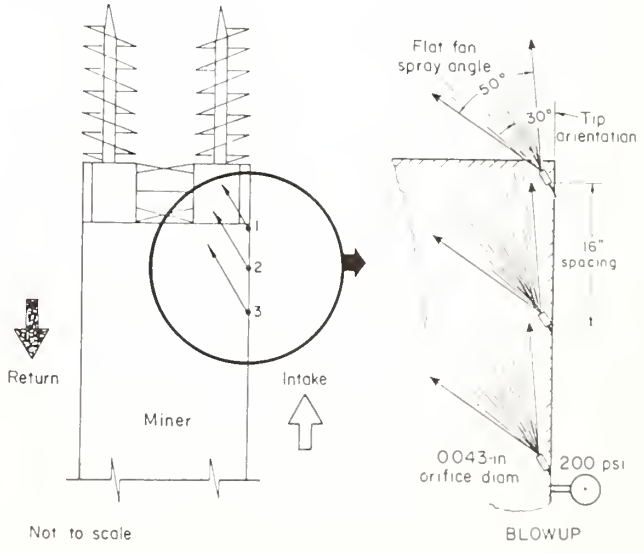


Figure 2.–Auger clearer spray system.

the return side of the miner and misting in this area did not cause a problem. The vertical orientations (toward the mine roof) of the sprays were adjusted so spray paths were not obstructed by the elevated cover plates located behind each auger head. The entire spray manifold was protected from roof fall material with 1/4-inch angle iron. A liquid strainer with an 80-mesh screen was used to filter mine water before it reached the manifold. None of the sprays clogged during the evaluation.

The surveyed mine was using the normal through-the-drum sprays (wet auger sprays) to reduce dust generation. The wet auger spray system was maintained throughout the underground evaluation, while the auger clearer (the auxiliary system) was switched on and off. Many of the face workers commented that the auger clearer appeared to reduce dust levels in the face area. This observation was supported by the collected data. The auger clearer reduced dust concentrations by about 30% at the intake jack setter location, and 25% at the miner operator and return jack setter locations.

Intended Use

A previous study showed that the wet auger spray system reduces auger miner dust generation by about 60%. Laboratory and underground tests indicate that the wet auger spray system can be enhanced by adding the auger clearer. The auger clearer was designed to complement the wet auger spray system. It should not be used as a replacement.

One potential disadvantage of the auger clearer was observed during the underground evaluation. Mist created by the auger clearer reduced the miner operator's visibility for the return side auger head. Reduced visibility did not appear to create a safety hazard at this particular operation. However, the impact of this condition should be considered by each operation before installing the auger clearer.

For More Information

Technology News 310 provides details on improved ventilation techniques for reducing auger mining dust levels. Technology News 322 provides details on an auger miner throat scrubber for dust reduction. Information concerning these studies, or additional information concerning the auger clearer study can be obtained by contacting:

J. Drew Potts
Pittsburgh Research Center
U.S. Bureau of Mines
P.O. Box 18070
Pittsburgh, PA 15236-0070
(412-892-4373)

New Technology from the Bureau of Mines

U.S. Department of the Interior Bureau of Mines

Effective Operation of Conveyor Belt Cleaning Systems

Objective

Reduce the number of conveyor-related accidents in the mining industry by providing recommendations for effective operation of conveyor belt cleaning systems.

The Problem

Troughed belt conveyors provide effective and efficient materials transport and their use has increased throughout the mining industry. Carryback, the spillage that accumulates under the belt, is a problem even with belt cleaning systems installed. Mining personnel are exposed to safety and health hazards as they attempt to clean up this spillage.

Approach

To investigate the influence of metal-segmented-blade belt cleaners on the amount of carryback spillage, the Bureau identified and tested the following parameters: (1) amount of pressure applied to the cleaner blades, (2) friction between the blades and conveyor belt, and (3) wear rates of different metal blades.

The test parameters were quantified by recording the amount of carryback material passing the metal cleaner blades and the weight loss of the blades. The data collected were used to identify the following critical operational parameters of a segmented-blade conveyor cleaner system: (1) the existence of an optimal operating pressure for the conveyor and cleaning systems and (2) elimination of recessed patterns on the working side of the conveyor belt.

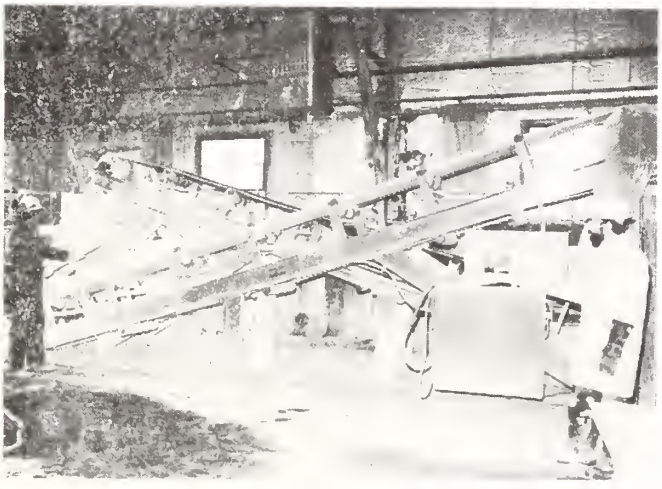
Test Facility

A full-sized conveyor test facility was constructed to gather the data. It consists of two 30-foot-long conveyors with 24-inch-wide belts and 24-inch-diameter pulleys. A special test fixture bracket was designed to hold test blades perpendicular to the rubber belt with air-actuated cylinders. The recycling conveyor was fitted with a large storage hopper to provide a constant sand-lime slurry mixture to the test runs.

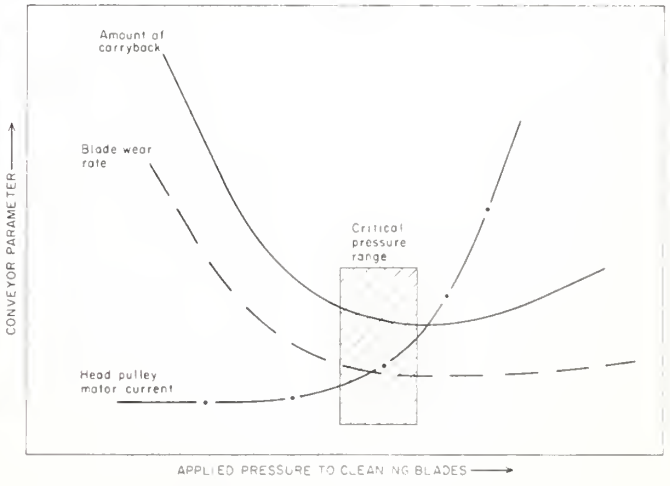
Investigation Results

Carryback rate and blade wear rate versus pressure curves indicate the existence of a critical pressure range. The critical pressure range for the test conveyor system was 11 to 14 psi applied to each cleaner blade. Above 14 psi no significant decrease in carryback was observed during the 8- to 24-hour test runs. Blade wear rate did not increase above this pressure but the conveyor belt-blade friction increased. The conveyor head pulley drive motor current increased 26% when the pressure applied to the blades was increased from 14 to 20 psi.

Nonuniform wear patterns were observed in the edge of all the cleaning blades during the 8- to 24-hour test runs. The channels or grooves worn into the blade edges were from abrasion and erosion caused by the sand particles and the slurry mass. Once the grooves were worn into the blades, increasing the blade-to-belt contact pressure did not eliminate the carryback. Metal blades (1/4 by 6 by 2 inches) made from mild stainless, alloy, and tool steel were tested. The Rockwell C hardness of the blades ranged from 11 to 50. The wear rates decreased with



Full-sized conveyor test facility consisting of two 30-foot-long conveyors with 24-inch-wide belts.



Critical (optimum) pressure applied to cleaning blades as defined by carryback, blade wear rate, and motor current of conveyor.

increasing hardness, but eventually the nonuniform wear pattern of peaks and valleys became visible and the carryback amount increased to 5 to 10 grams per square foot. Wear rates varied from 1 to 6 mils per year for the test blades.

Company logos or other patterns recessed into the conveyor belt working side allowed material to be carried between the blade and belt, which accelerated blade wear by 55% to 60%. The wear pattern of the metal blade edge will be characteristic of the recessed pattern filled with the conveyed material in the belt.

This study showed the existence of a critical operating pressure applied to belt cleaning blades for maximum cleaning and minimum wear of the blades and belt. Cleaner blade service life can be lengthened by using metal with greater hardness. All advantages can be negated with any defect on the belt surface that allows additional carryback. This additional carryback will shorten the cleaning system's service life and increase maintenance around operating conveyors.

For More Information

Additional details concerning this research are available in U.S. Bureau of Mines Report of Investigations (RI) 9221, "Basic Parameters of Conveyor Belt Cleaning." For a free single copy of this RI, write to the Bureau's Publications Distribution Section, Bldg. 149, P.O. Box 18070, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

For answers to technical questions or additional details, please contact the Bureau's investigators for this research:

Terry L. Hebble or Charles A. Rhoades
Twin Cities Research Center
U.S. Bureau of Mines
5629 Minnehaha Avenue South
Minneapolis, MN 55417-3099
(612-725-4500)

FOR ADDITIONAL INFORMATION: A contract report, "Safety Evaluation of Conveyer Belt Cleaning Systems," is available from the National Technical Information Service (NTIS). To obtain a copy, specify report PB 83-262592 and send $16.95 to NTIS, 5285 Port Royal Road, Springfield, VA 22161.

Price code: A04

Timber Bridge Program

This stressed-deck bridge was installed as a demonstration of new timber bridge technology.

In 1989, the USDA Forest Service began a program to respond to the renewed interest in using timber as a construction material for bridges. Timber bridges offer an economical, durable, safe, and attractive alternative to traditional materials used for bridge construction. Timber bridges are of growing interest because they are economically competitive with other materials and designs, perform well, and are easy to construct and install.

The Forest Service initiative established a Timber Bridge Information Resource Center for technical assistance, funded cost-share demonstration bridges, and expanded timber bridge research. The Center's program is to inform state, county, and local officials, federal agencies, engineers, and contractors about the advantages of using properly treated timber for new and replacement bridges on local and secondary road systems and public properties. The Center also administers the selection and installation of the demonstration bridges.

Through cost-share funding, at least 80 bridges will be constructed nationwide to demonstrate modern timber design concepts. The demonstration bridges emphasize the utilization of native species to stimulate local employment and rural economics.

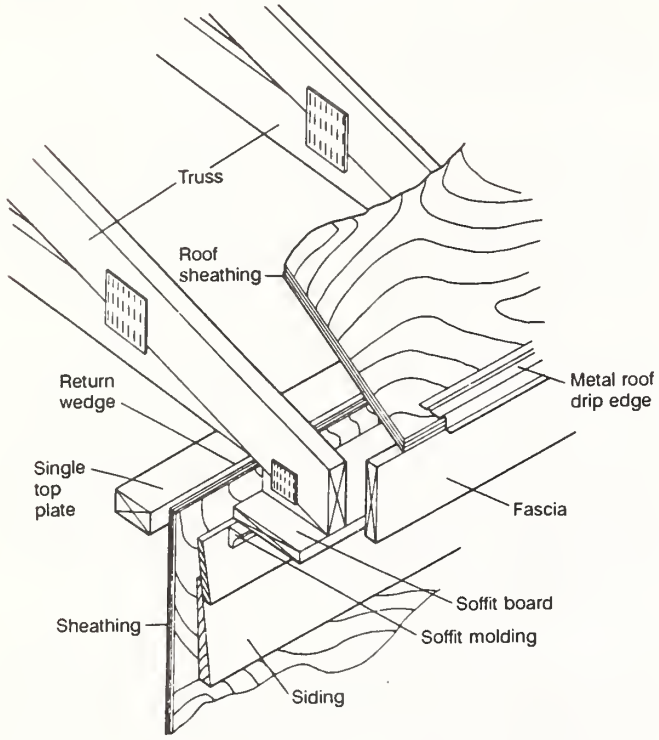
Performance data from some of these demonstration bridges will be used to obtain approval of new designs from the American Association of State Highway Transportation Officials (AASHTO). Existing AASHTO standards will also be refined to reflect current timber bridge technologies, such as crash-tested guardrail designs and timber from species not formerly used.

AASHTO design standards are recognized nationally and keep transportation systems uniform. They are usually a basis for funding approval by the Federal Highway Administration and state transportation agencies. AASHTO approval of new timber bridge technologies is necessary if timber is to be a viable alternative in many locations, because local projects often receive partial funding from federal or state agencies.

Research is continuing to refine some of the newest designs and develop recommended design criteria. Studies are also being conducted to optimize species availability, treatability, and performance. Researchers are developing and crash testing guardrail designs to provide standard systems that comply with recommended AASHTO guidelines for crashworthy railings. Economic studies are being conducted to better compare the costs of alternative materials and to calculate life cycle costs, including initial costs, maintenance, and longevity.

For additional information, contact:
John B. Crist
Program Manager
Timber Bridge Information Resource Center
USDA Forestry Sciences Lab
180 Canfield Street
Morgantown, WV 26501
(304) 291-4159

Wood-Frame House Construction



Sample of detailed diagrams included in *Wood-Frame House Construction.*

The newly revised *Wood-Frame House Construction*, Agriculture Handbook 73, presents sound principles for building homes and guidelines for selecting materials that will provide long service. As a construction guide, the handbook delineates sound building practices for experienced builders, apprentices, and do-it-yourselfers alike. As a textbook, it provides basic information to the student. As a standard, it provides a basis for judging the quality of residential construction. Since its first edition in 1955, this manual has been the authoritative guide to wood-frame house construction.

The manual begins by describing preconstruction considerations and a general schedule for completion. The next three chapters describe laying the groundwork, framing and closing in, and completing the shell. Chapter 5 discusses specialty items such as fireplaces, chimneys, porches, and driveways. The remaining chapters describe interior work, finishing touches, and special topics such as protection from decay and termites, noise control, and wind, snow, and seismic loads. The manual also contains an annotated bibliography and a glossary.

Completely rewritten in 1989, this 266-page manual reflects major new advances in home building during the past decade. Its new features include the chapter on preconstruction and technical notes on concrete, treated wood, lumber and plywood grades, nail selection and use, heat flow, and insulation. Also added were information on new materials and the use of manufactured components, greatly expanded discussion of energy conservation and efficiency, tables of engineering design data for structural elements, and an expanded and annotated list of additional readings.

This new edition draws upon the combined knowledge of industry and government to present the state of the art in wood home construction. The Research Center of the National Association of Home Builders and the USDA Forest Service, Forest Products Laboratory, jointly prepared the manual, with the cooperation of the Canadian Wood Council, National Forest Products Association, National Lumber and Building Materials Association, U.S. Department of Housing and Urban Development, and many individual experts.

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For additional technical information, contact:
Russell C. Moody, Research General Engineer
Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53705–2398
(608) 231–9227

NASA Tech Brief
National Aeronautics and
Space Administration

Combining Thermal and Structural Analyses

A computer code makes programs compatible so that stresses and deformations can be calculated.

A paper describes a computer code that combines thermal analysis with structural analysis. Called SNIP (for SINDA-NASTRAN Interfacing Program), the code provides an interface between a finite-difference thermal model of a system and a finite-element structural model of it when there is no node-to-element correlation between the models. SNIP eliminates much of the manual work in converting the temperature results of the SINDA (Systems Improved Numerical Differencing Analyzer) program into thermal loads for the NASTRAN (NASA Structural Analysis) program.

SNIP generates thermal-load cards for NASTRAN plate, shell, bar, and beam elements so that thermal deformations and stresses in the structure can be predicted. SNIP uses a geometric search routine and a numerical coding scheme to relate thermal-model nodes to structural-model elements. It then calculates element temperatures according to the weighted averages of temperatures of the thermal nodes related to each element. Users can vary input parameters to control the correlations between nodes and elements.

SNIP is being used to analyze concentrating reflectors for the solar generation of electric power. Large thermal and structural models are needed to predict the distortion of surface shapes, and SNIP saves considerable time and effort in combining the models.

The code has already been applied to the analysis of thermal deformations of satellite antenna reflectors. It furnished accurate results in a fraction of the time of other model-combining methods. An important side effect was that SNIP induced a high level of communication between thermal and structural modelers, and errors in the models thus became obvious early in the development of the models.

This work was done by Steven R. Winegar of **Lewis Research Center**. *Further information may be found in NASA TM-100158 [N87-27268], Price Code: A03 "SINDA-NASTRAN Interfacing Program Theoretical Description and User's Model."*

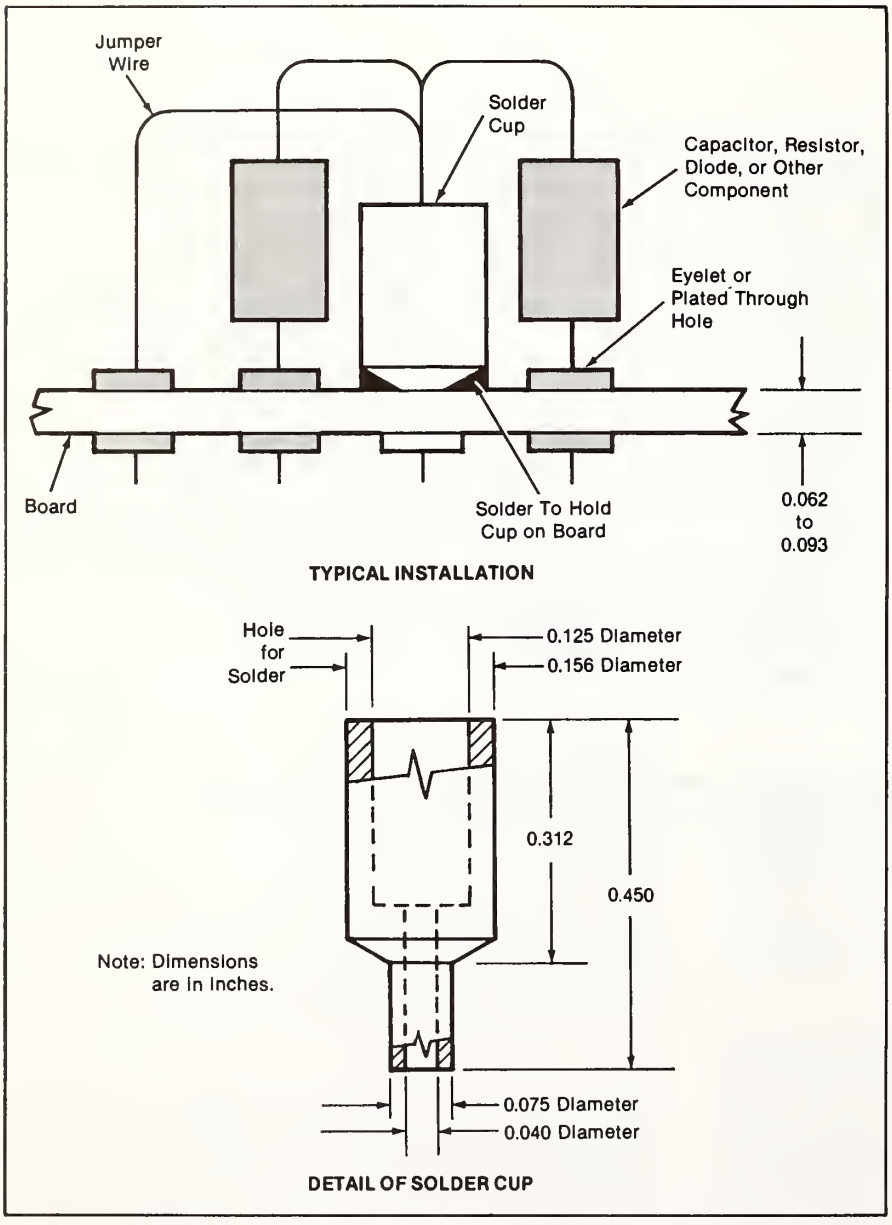
Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14741/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Connecting Multiple Wires to a Single Through Hole

A solder cup would make it easier to rework printed-circuit boards.



Jumper Wires and Leads from components would be joined to a single through hole by a solder cup.

A small cup would enable more than one wire to be soldered to a plated through hole in a printed-circuit board. Normally, a through hole can accommodate only one wire. However, the relatively wide mouth of the cup would hold at least three wires and connect them electrically through its solder contents (see figure).

Cups of this type could be used on breadboard circuits and on newly-manufactured circuit boards. They would be particularly useful in the modification of circuit boards, where they would serve as convenient attachment points for jumper wires and the leads of added components.

The cups would be made of brass plated with silver. They would be inserted in eyelets or plated through holes and swaged onto the boards.

This work was done by Reuben G. Cortes of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29405/TN

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Electrostatic Linear Actuator

Electrically charged helices would attract or repel each other.

A proposed electrostatic linear actuator would be made with intertwined dual helices, which would hold the charge-bearing surfaces. The dual-helix configuration would provide relatively large unbroken facing charged surfaces (and, thereby, relatively large electrostatic force) within a small volume. The spiral form would also make the components more rigid. The actuator was conceived to have few moving parts and to be operable after long intervals of inactivity.

The actuator would include an inner helix on a shaft within an outer helix, resembling a lead screw in a loosely fitting nut (see Figure 1). However, no rotary motion would be involved. The shaft could even be restrained against rotation after initial threading of the helices together during assembly. The output motion would be purely axial translation of the shaft, within the limits of the axial gaps between the helices.

The pitch of the helices would be selected to provide gaps large enough to permit the full axial translation desired, yet small enough to provide adequate electrostatic attraction and repulsion. Both helices would be made of plastic or other electrically-insulating material. Both large faces of each helix would be covered by conductive films, which would in turn be covered by thin insulating films to prevent conduction between facing conductive films when the helices touch (see Figure 2). Thus, a substantial electric charge could be stored in the conductor on each face of each helix.

The placement of charges of the appropriate polarities on the conductors would cause attractions and/or repulsions between the conductors, thereby pushing the inner helix along the axis with respect to the outer helix. For example, charges of the polarities indicated in Figure 2 would push the inner helix to the right. The general rule of operation is to place opposite charges (which attract) across a gap that is to be shortened, and like charges (which repel) across a gap that is to be lengthened.

The inner helix could be held so that the outer helix could move, or vice versa. Alternatively, each could be held and released in alternation in synchronization with reversals of charges to obtain a ratcheted crawling motion. In an alternative configuration, the helices could be replaced by flat surfaces perpendicular to the axis, reminiscent of a parallel-plate capacitor. In that case, the actuator would have to be assembled by sideways insertion of the shaft and its plates into longitudinally split halves of the housing and its plates.

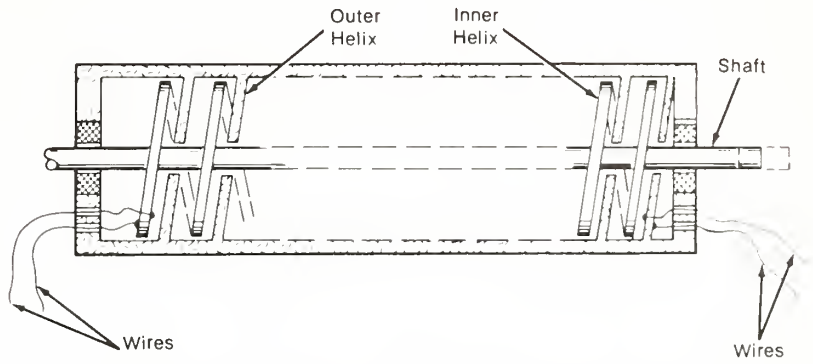

Figure 1. The **Inner Helix Would Slide Axially** in the outer helix in response to voltages applied to the conductors.

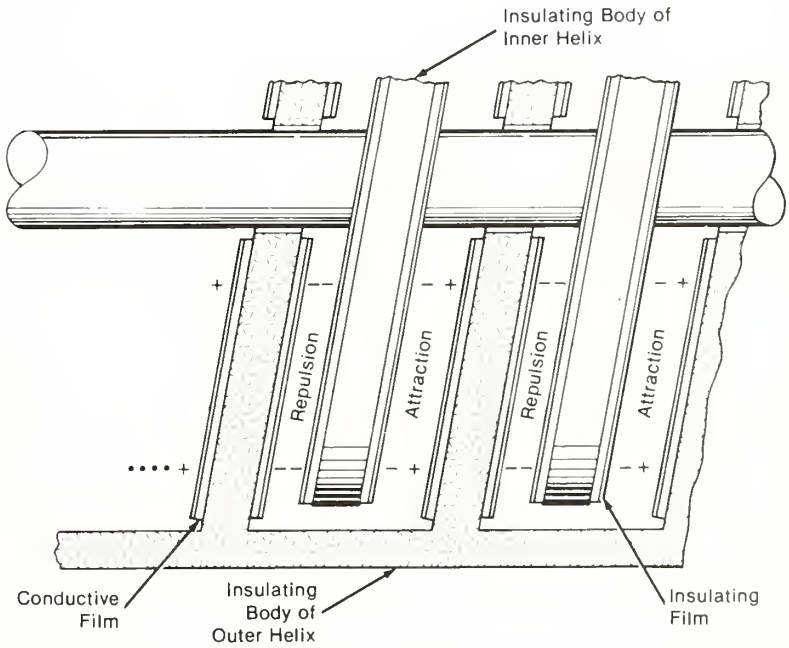

Figure 2. The **Inner Helix and Shaft** would be pushed to the right when the conductors are charged with the indicated polarities.

This work was done by Earl R. Collins, Jr., and Kenneth C. Curry of Caltech for **NASA's Jet Propulsion Laboratory.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL. Refer to NPO-17684/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Hot Wax Sweeps Debris From Narrow Passages

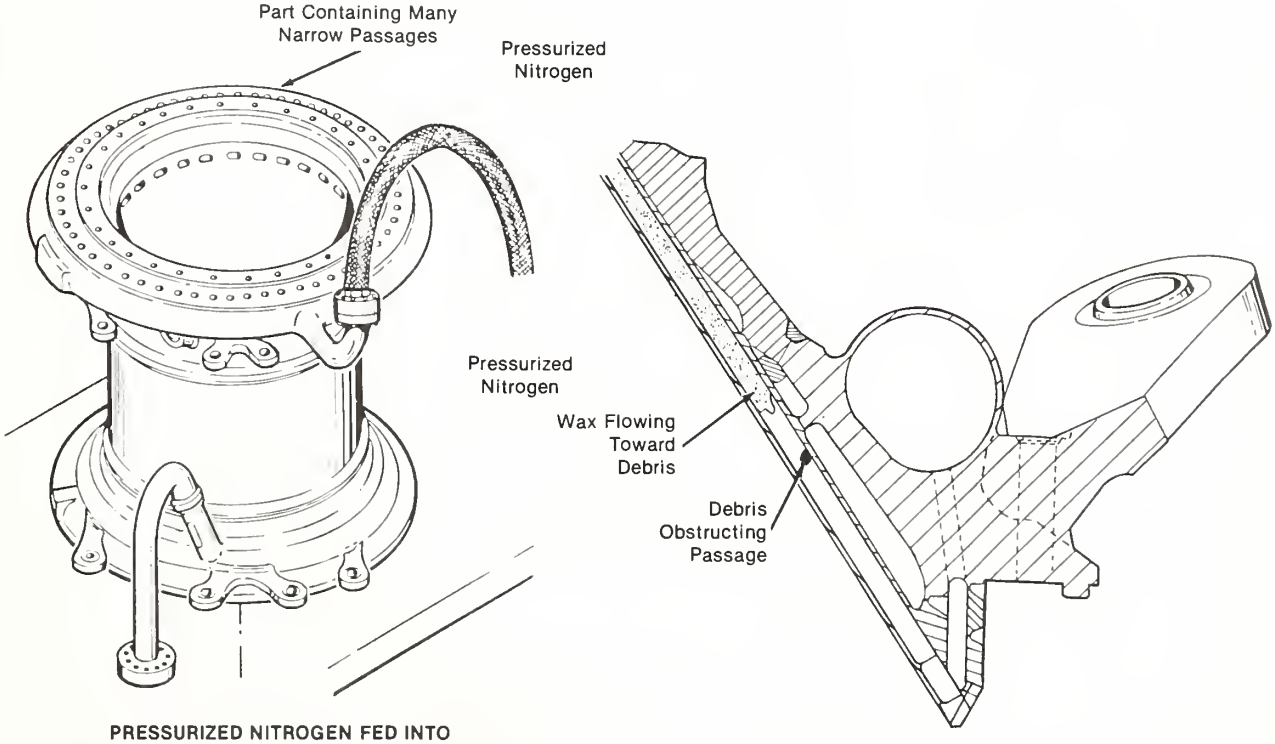
Loose particles are removed from inaccessible places.

A safe and effective technique for the removal of debris and contaminants from narrow passages involves the entrainment of the undesired material in a thermoplastic casting material. Devised to clean out fuel passages in the main combustion chamber of the Space Shuttle main engine, the technique could also be applied to narrow, intricate passages in internal-combustion-engine blocks, carburetors, injection molds, and other complicated parts.

First, the debris are located by radiography (which detects metal) or infrared imaging (which detects nonmetallic objects). Next, the part is heated to 300 °F (149 °C), and Rigidax (or equivalent) casting wax, melted in a separate vessel at 300 °F, is poured into the passage in sufficient quantity to reach the debris. The part is allowed to cool at room temperature so that the wax hardens.

The part is then reheated to a temperature of 250 to 275 °F (121 to 135 °C), just below the melting point, at which the wax is semisolid. Pressurized nitrogen is supplied to one end of the passage to extrude the wax along the passage and out one end, carrying the debris with it (see figure). The small amount of wax and contamination remaining in the part is then removed by conventional dewaxing and cleaning procedures.

This work was done by Steven K. Ricklefs of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29462 /TN*



PRESSURIZED NITROGEN FED INTO MANIFOLD CONNECTED TO AFFECTED PASSAGE

DETAIL OF WAX FLOWING IN AFFECTED PASSAGE

Semisolid Wax slightly below the melting temperature is pushed along a passage by pressurized nitrogen to remove debris.

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Licensing Opportunity

Measuring Diameters of Large Vessels

A computerized apparatus produces accurate results quickly.

An apparatus measures the diameter of a tank or other large cylindrical vessel, without a priori knowledge of the exact location of the cylindrical axis. The apparatus produces a plot of the inner circumference, an estimate of the true center of the vessel, data on the radius, the diameter of a best-fit circle, and the negative and positive deviations of the radius from the circle at closely spaced points on the circumference. It eliminates the need for time-consuming and error-prone manual measurements.

A crossbeam assembly is bolted to the vessel by brackets (see figure). Suspended from the center of the crossbeam assembly is a movable radius arm. A servomotor and gear train rotate the arm so that it pivots about an axis at the intersection of the crossbeams. As the arm rotates, an electronic linear gauge at the end of the arm is spring-loaded against the inner wall of the vessel. The gauge extends and retracts to follow the wall contour, generating an electrical signal that represents the radius at any instant. The signal is fed through a cable to a computer and printer on a cart.

The circumferential speed of the measuring tip is about 5 in./s (12.7 cm/s). An angle resolver on the shaft that rotates the radius arm generates an electrical signal that represents the rotational position of the arm. This signal is also fed to the computer.

The computer thus obtains data on the length of the arm as a function of the angular position of the arm as it sweeps around the vessel. From the data, the computer calculates the radii, diameter, true center, and deviations from true circularity. The computer also controls the operation of the apparatus by turning the power switch on and off to start and stop the measurements.

This work was done by James R. Currie, Ralph R. Kissel, Charles E. Oliver, Earnest C. Smith, John W. Redmon, Sr., Charles C. Wallace, and Charles P. Swanson of **Marshall Space Flight Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Marshall Space Flight Center. Refer to MFS-28287/TN.

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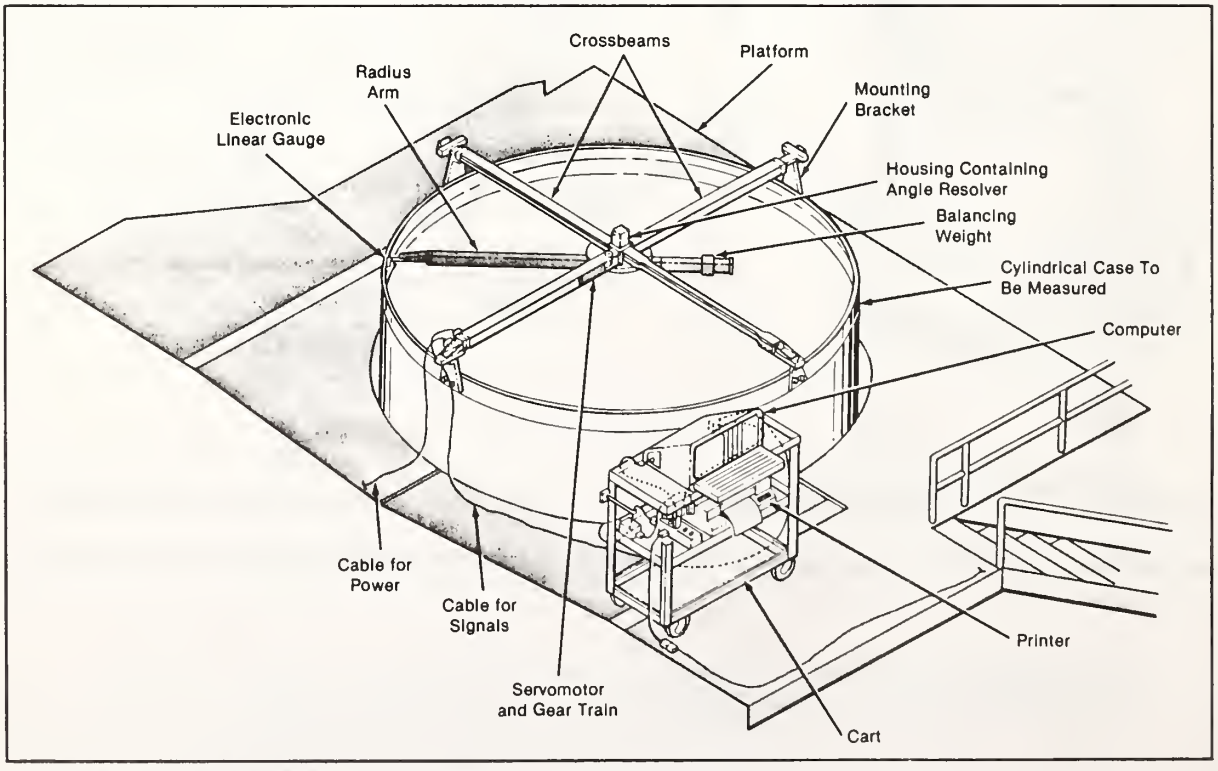

The Intersection of the Crossbeams need not be positioned exactly at the center of the vessel. The time required to set up the apparatus for measurements is therefore much shorter than it would be for manual measurements of the radii from a precisely determined center. The computer processes the data from the automatic measurements to find the center.

NASA Tech Brief
National Aeronautics and
Space Administration

Numerical Analysis of Flows With FIDAP

Predictions of FIDAP are compared with other numerical results and with data from experiments.

A report presents an evaluation of the accuracy of the Fluid Dynamics Package (FIDAP) computer program. FIDAP is a finite-element code for the analysis of flows of incompressible fluids and transfers of heat in multidimensional domains. It includes both of the available methods for the treatment of the spurious numerical coupling between the simulated velocity and the simulated pressure; namely, the penalty method and the mixed-interpolation method with variable choices of interpolation polynomials for velocity and pressure. The streamwise upwind (STU) method is included as an option for flows dominated by convection.

In this study, FIDAP was applied to four two-dimensional problems: laminar flow in a wall-driven cavity, laminar flow over a backward-facing step, turbulent flow over a backward-facing step, and turbulent flow through a turnaround duct. In all cases, the nine-node quadrilateral finite element with linear discontinuous interpolations for pressure was used. This approach is known from previous studies to be one of the optimal choices for the treatment of the spurious numerical velocity/pressure coupling in incompressible flow. The penalty parameter was chosen to be 10^{-6}. The flows predicted by FIDAP were compared with the flow predicted by other numerical methods and/or the corresponding measured flows.

The following conclusions were drawn from the study:

- The consistant-integration-penalty, finite-element program with the quadrilateral finite elements described previously can be used to treat the spurious numerical velocity/pressure coupling in the flow of an incompressible fluid.
- When STU is used, the numerical diffusions are too strong in high-Reynolds-number laminar flow, particularly inside a wall-driven cavity.
- When STU is not selected, the numerical results of FIDAP for laminar flow agree well with the predictions of other numerical methods and with measurements.
- STU is essential to the computation of turbulent flow because it stabilizes numerical solutions of the equations of the $k-\varepsilon$ mathematical model of turbulence proposed by Launder and Spalding. However, momentum equations are strongly influenced by STU, and numerical diffusions in the velocity field must, therefore, be minimized by the application of higher-order upwinding techniques to momentum equations.
- The predictions of FIDAP correspond to the general trends in the predictions of other methods for the $k-\varepsilon$ model of turbulence. Discrepancies between the predictions and measurements in both test cases for turbulent flow are caused mainly by the limitations of the standard $k-\varepsilon$ model on recirculating and curved flows. Advanced mathematical models of turbulence should be incorporated into FIDAP to obtain accurate predictions of turbulent flows.

This work was done by Jeong L. Sohn of **Marshall Space Flight Center**. *Further information may be found in NASA CR-179390 [N89-10253], Price Code: A04 "Numerical Analysis of Laminar and Turbulent Incompressible Flows Using the Finite Element 'Fluid Dynamics Analysis Package (FIDAP)'."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
MFS-27219/TN

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NASA Tech Brief
National Aeronautics and
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Perspectives on Dilution Jet Mixing

A study identifies effects of flow and geometric parameters on mixing of transverse jets with ducted crossflow.

NASA recently completed a program of measurements and modeling of the mixing of transverse jets with a ducted crossflow, which was motivated by the need to design or tailor the temperature pattern at the combustor exit in gas turbine engines. Problems of jets-in-crossflow have been studied frequently due to their appearance as constituent flows in such diverse applications as pollutant dispersion from chimneys, thermal discharges into rivers and streams, overfire jets in furnaces, engine exhaust from VSTOL (Vertical/Short Takeoff and Landing) aircraft, gas turbine combustor exit temperature pattern control, and fuel injection in high speed propulsion systems. The information obtained in any given study may, in addition to increasing the understanding of the more general problem, be directly relevant to the solution of similar problems in very different applications.

The combustor dilution zone jet-in-crossflow application is a confined mixing problem, with from 10 to 50 percent of the total airflow entering through dilution jets in the aft section of the combustor. The result is that the average temperature of the exiting flow may differ significantly from that of the entering mainstream flow. To control or tailor the exit temperature pattern, it is necessary to be able to characterize the exit distribution in terms of the upstream flow and geometric variables.

The objectives of this program were to identify the dominant physical mechanisms governing the mixing, extend empirical models to provide a near-term predictive capability, and compare numerical code calculations with data to guide future analysis improvement efforts. Mean temperature measurements have been analyzed to identify the principal independent flow and geometric variables affecting the mixing. These measurements are compared with calculations made with both empirical and numerical models for flow and geometric variations typical of many gas turbine combustors.

This work was done by J. D. Holdeman of **Lewis Research Center** *and R. Srinivasan of Garrett Turbine Engine Co. Further information may be found in NASA TM-87294 [N86-32432], Price Code: A03 "Perspectives in Dilution Jet Mixing."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

For tutorial slide show, contact J.D. Holdeman at Lewis Research Center. LEW-14614/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
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NASA Tech Brief
National Aeronautics and Space Administration
Lewis Research Center, Cleveland, Ohio

Licensing Opportunity

Post Clamp With Attached Collar

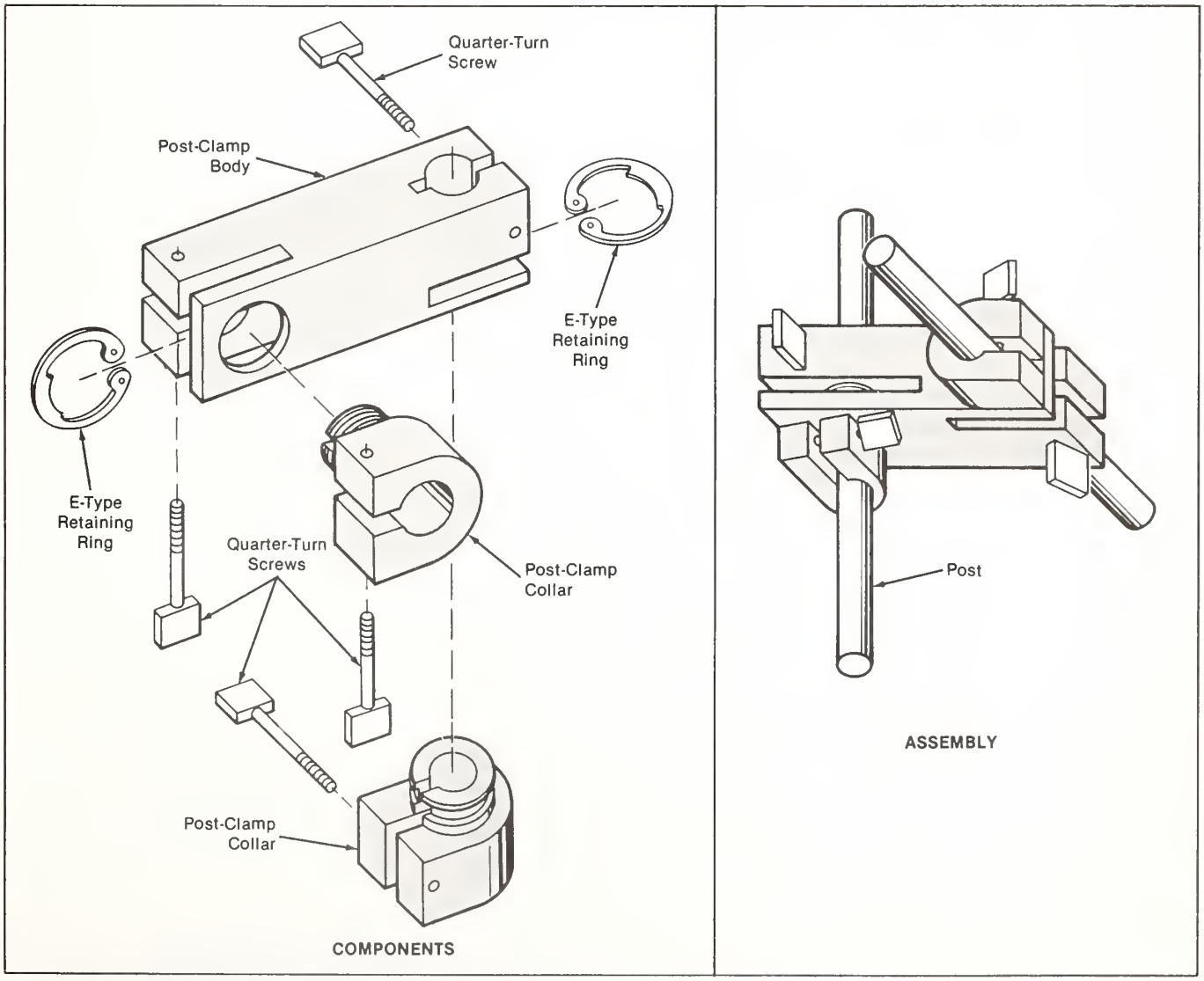
The collar makes adjustment of optical components easier and faster.

A new clamp for optical posts can reduce the time required to set up optical components. Like earlier clamps, the new clamp joins a pair of perpendicular posts supporting a laser, lens, reflector, or other optical component and enables the posts to be rotated in perpendicular planes so that the orientation and position of the component can be adjusted. The new clamp can be adjusted with only half the number of steps required by older clamps and separate post collars. Inasmuch as adjustments have to be made again and again for many components in an optical setup, the reduction in the number of steps adds up to a significant reduction in setup time. Moreover, the new clamp, unlike some older ones, does not tend to mar a post.

The post-clamp body retains post-clamp collars with E-type retaining rings (see figure). A mounting post is inserted through the hole in a post-clamp collar and the corresponding hole in the post-clamp body. Quarter-turn screws in the collar and body are tightened to reduce the diameters of the holes and thereby grip the post. A second post is inserted in the other hole in the body (at a right angle to the first post) and clamped in the same way.

To translate and rotate the clamp on a post, a user follows this procedure:

- Loosen the quarter-turn screws on the body and collar that secure the clamp assembly to the post. Slide the clamp along the post to the desired axial position. Tight-



The Principal Advantage of the New Post Clamp is conferred by its E-type retaining rings, which hold the post-clamp collars to the post-clamp body. A collar can be tightened around a post to prevent movement along a post while allowing the clamp to turn around that post. Quarter-turn screws on the body and collars tighten the parts on posts.

en the screw in the post-clamp collar.

- Rotate the clamp on the post to the desired angular position. Tighten the screw in the post-clamp body.

One of the advantages of the new clamping assembly is that the loosened body can even be suspended on, and rotated about, the tightened collar. Thus, for example, the user can rotate the body on a vertical post without supporting it from below with a separate collar or by hand to prevent it from falling along the post. This convenience is not offered by older clamps.

The new collar makes contact with the post uniformly around its circumference, thus distributing the gripping force evenly. In some older types of collar, in contrast, it is necessary to drive a thumbscrew directly into contact with the post to secure it, applying a concentrated force on a small area of the post. If excessive torque is applied to these thumbscrews, it is possible to mar or scratch the post if the thumbscrew is made of a harder material than the post, making subsequent readjustments of the clamp at the same spot even more difficult.

This work was done by John Karl Ramsey and Erwin H. Meyn of **Lewis Research Center.**

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center. Refer to LEW-14862/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Robot Hand Would Adapt to Contours

A conceptual device would use hydraulic pressure to activate fingers.

Projections on the opposing fingers of a proposed robot hand would automatically conform to the contours of an object on contact. The hand could therefore be used to grasp objects of various shapes and sizes. The conforming process would be passive; the pressure of the object on one or several pad elements would force the other pad elements to touch it. The hand would not use elaborate mechanisms involving motors, cams, and cables.

The projecting elements on each finger would be pistons connected to a common hydraulic reservoir within the finger (see Figure 1). The reservoir is initially filled and sealed, with the pistons at the midpoint of their travel. The application of a force to one piston would cause a pressure to be exerted equally on all the other pistons. The diameters of the pistons near the middle of the finger would be less than the diameters of pistons near the edge. Therefore, the middle pistons would tend to move farther under an increase in pressure in the reservoir and to exert smaller forces. A gimbaled pad at the tip of each piston would tilt to align with the local surface of an object.

When the finger approached a flat-surfaced object head-on, all pads would contact the object simultaneously (see Figure 2). If the hand approached at an angle, the pistons would push the object into a position in which the pistons would be uniformly displaced, as though the finger had approached head-on.

When the finger approached a small sphere or cylinder, the middle piston would contact the object first. Because of its small diameter, it would tend to travel farther than the other pistons and would thus allow the round surface to sink in farther for a more secure grip. The hydraulic pressure generated by the middle piston would move its neighbors outward to meet the object. As they made contact, their tip pads would tilt to the local slope of the surface of the object. The pistons would interact similarly in contacting irregular objects and concave objects.

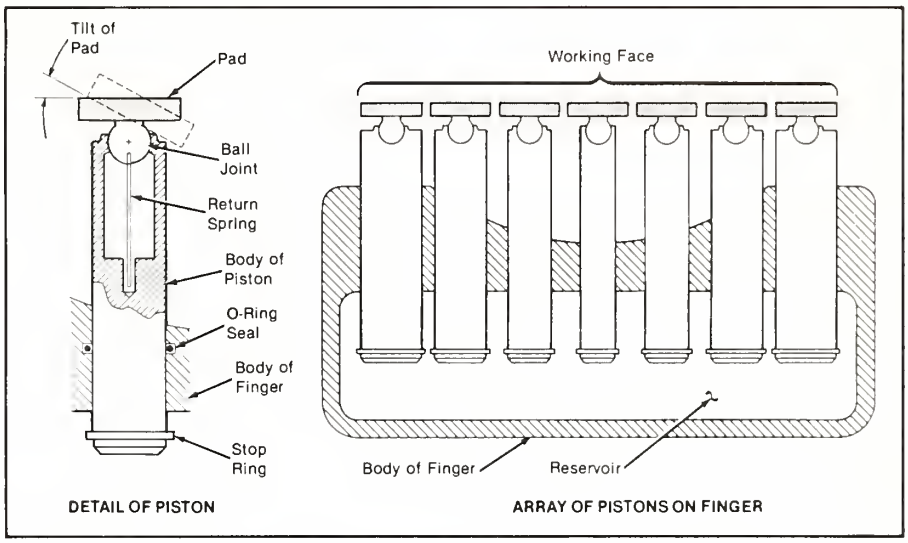

Figure 1. **Pistons Connected to a Common Reservoir** would provide a gentle, firm grip. The fingers would communicate with each other via the hydraulic pressure, without an elaborate control system.

The pistons would tend to center a symmetrical object like one with a spherical or flat surface because the piston forces would decrease toward the middle of the finger. An offcenter object would be subjected to higher forces at the side farthest from the center. The tilted pads would then exert sideways forces that would slide the object inward.

The same gradation of forces would inhibit rolling of an object. The object would become cradled securely in the pads without excessive force.

A sensor could monitor the pressure in the reservoir, and the pressure could be limited to prevent the pistons from damaging an object. No other sensing or control would be needed.

This work was done by Earl R. Collins, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL. Refer to NPO-16766/TN.

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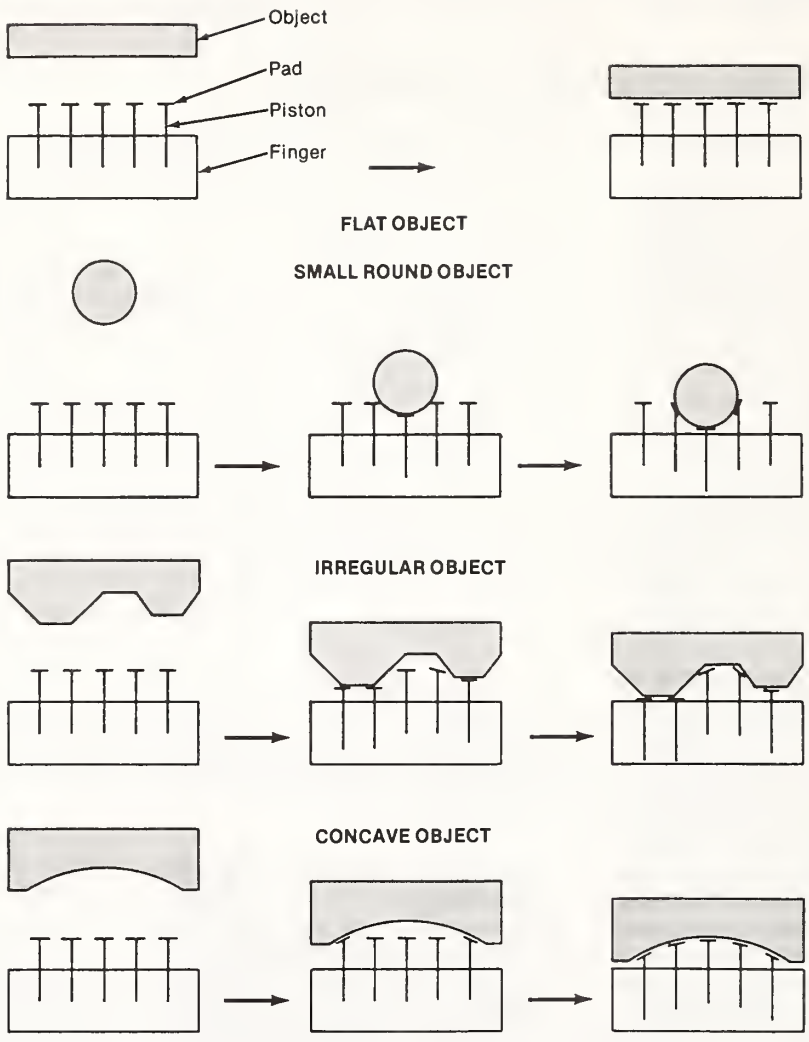

Figure 2. **Pistons Would Move In and Out**, and their tips would slope to match the contour of an object. Their action would tend to center the object on the finger.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Stowable Mechanical Sound Suppressor

A drive-and-link assembly actuates a system aft of the variable nozzle of an engine.

The concept of redirecting the exhaust gas of a jet engine in thrust-reversal and vectored-thrust applications has been the subject of considerable research and development for many years. Now, with increased emphasis on the suppression of the noise generated by jet engines, a stowable sound suppressor has been conceived for high-speed commercial transport (HSCT) engines. The suppressor is to be located just aft of the variable nozzle of the engine.

During takeoff, when suppression of noise is required, a multisegmented system of separators is rotated out of a center plug across the nozzle stream. Actuation is accomplished by a single ball-screw drive and links, similar to the spokes in an umbrella. With the iris nozzle translated forward, a circumferential row of tubes is exposed. The pattern of tubes and separators form the suppressor configuration. The flow stream through the slots and tubes is sized to the takeoff area.

For positions other than takeoff, the separator portion of the suppressor is rotated back into the tail cone to the stowed position, out of the airstream. The holes in the tube assembly are blocked by a sequenced iris nozzle that also sets the exhaust-throat area. A segmented, spring-loaded door attached to each of the separators blocks the flow of air through the tail cone when the suppressor is in the takeoff position and is translated inward when the suppressor is in the stowed position. In addition to being useful in HSCT engines, the stowable mechanical sound suppressor should be useful on any turbojet engine in which active suppression of sound is a requirement.

This work was done by Edward R. Thompson of United Technologies Corp. for **Langley Research Center**. *No further documentation, is available. LAR-14158/TN*

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Environmental Science & Technology

0576 State of Technology Review: Soil Vapor Extraction Systems

0577 Effects of Acidic Rain on Wood and Painted Wood

Other Items of Interest

0543 Can Crops Tolerate Acid Rain

0558 Destroying Toxic Wastes

United States
Environmental Protection
Agency

Risk Reduction
Engineering Laboratory
Cincinnati, OH 45268

Research and Development

EPA

Project Summary

State of Technology Review: Soil Vapor Extraction Systems

Introduction

Soils may become contaminated in a number of ways with such volatile organic chemicals as industrial solvents and gasoline components. The sources of contamination at or near the earth's surface include intentional disposal, leaking underground storage tanks, and accidental spills. Contamination of groundwater from these sources can continue even after discharge has stopped because the unsaturated zone above a groundwater aquifer can retain a portion or all of the contaminant discharge. As rain infiltrates, chemicals elute from the contaminated soil and migrate toward groundwater.

Alternatives for decontaminating unsaturated soil include excavation with on-site or off-site treatment or disposal, biological degradation, and soil flushing. Soil vapor extraction is also an accepted, cost-effective technique to remove volatile organic chemicals from contaminated soils. Among the advantages of the soil vapor extraction process are that it minimally disturbs the contaminated soil, it can be constructed from standard equipment, it has been demonstrated at pilot- and field-scale, it can be used to treat larger volumes of soil than are practical for excavation, and it has a potential for product recovery. With vapor extraction, spills can be cleaned up before the chemicals reach the groundwater table. Soil vapor extraction technology is often used with other clean up technologies to provide complete restoration of contaminated sites.

A large number of pilot- and full-scale soil vapor extraction systems have been constructed and studied under a wide range of conditions. The information gathered from these experiences can be used to deduce the effectiveness of this technology. One of the major objectives of the Report is to review available reports describing current practices critically and to summarize this information as concisely as possible. A brief description of a typical vapor extraction system is presented. The experience with existing extraction systems has been reviewed, and information about each system is briefly summarized in a standard form.

System Components

Extraction wells are typically designed to fully penetrate the unsaturated zone to the capillary fringe. Extraction wells usually consist of slotted elastic pipe placed in permeable packing.

System Operations

During remediation, the blower is turned on and the air flow through the soil comes to an equilibrium. The flows that are finally established are a function of the equipment, the flow control devices, the geometry of well layout, the site characteristics, and the air permeability of the soil. At the end of operation, the final distribution of VOCs in the soil can be measured to ensure decontamination of the site. Wells may be aligned vertically or horizontally. Vertical alignment is typical for deeper contamination zones and for residue in radial flow patterns. If the depth of the contaminated soil or the depth to the groundwater table is less than 10 to 15 ft, it may be more practical to dig a trench across the area of contamination and install horizontal perforated piping in the trench bottom rather than to install vertical extraction wells. Usually several wells are installed at a site.

System Variables

A number of variables characterize the successful design and operation of a vapor extraction system: site conditions, soil properties, control variables, response variables and chemical properties. The specific variables belonging to these groups include:

Site Conditions: distribution of VOCs, depth to groundwater, infiltration rate, location of heterogeneities, temperature, atmospheric pressure.

Soil Properties: permeability, porosity, organic carbon content, soil structure, soil moisture characteristics, particle size distribution.

Control Variables: air withdrawal rate, well configuration, extraction well spacing, vent well spacing, ground surface covering, inlet air VOC concentration and moisture content, pumping

duration.

Response Variables: pressure gradients, final distribution of VOCs, final moisture content, extracted air concentration, extracted air temperature, extracted air moisture, power usage.

Chemical Properties: Henry's constant, solubility, adsorption equilibrium, diffusivity (air and water), density, viscosity.

Well Design and Placement

Well spacing is usually based on some estimate of the radius of influence of an individual extraction well. In the studies reviewed, well spacing has ranged from 15 to 100 ft. Well spacing should be decreased as soil bulk density increases or the porosity of the soil decreases. One of the major differences noted between systems was the soil boring diameter. Larger borings are preferred to minimize extracting liquid water from the soil.

In the simplest soil vapor extraction systems, air flows to an extraction well from the ground surface. To enhance air flow through zones of maximum contamination, it may be desirable to include air inlet wells in the installation. These injection wells or air vents, whose function is to control the flow of air into a contaminated zone, may be located at numerous places around the site. Typically, injection wells and air vents are constructed similarly to extraction wells. In some installations, extraction wells have been designed so they can also be used as air inlets. Usually, only a fraction of extracted air comes from air inlets. This indicates that air drawn from the surface is the predominant source of clean air.

The design and operation of soil vapor extraction systems can be quite flexible; changes can be made during the course of operation with regard to well placement, or blower size, or air flows from individual wells. If the system is not operating effectively, changes in the well placement or capping the surface may improve it.

Conclusions

Based on the current state of the technology of soil vapor extraction systems, the following conclusions can be made:

1. Soil vapor extraction can be effectively used for removing a wide range of volatile chemicals in a wide range of conditions.
2. The design and operation of these systems is flexible enough to allow for rapid changes in operation, thus, optimizing the removal of chemicals.
3. Intermittent blower operation is probably more efficient in terms of removing the most chemical with the least energy.
4. Volatile chemicals can be extracted from clays and silts but at a slowerrate. Intermittent operation is cer-tainly more efficient under these conditions.
5. Air injection has the advantage of controlling air movement, but injection systems need to be carefully designed.
6. Extraction wells are usually screened from a depth of from 5 to 10 ft below the surface to the groundwater table. For thick zones of unsaturated soil, maximum screen lengths of 20 to 30 ft are specified.
7. Air/water separators are simple to construct and should probably be installed in every system.
8. Installation of a cap over the area to be vented reduces the chance of extracting water and extends the path that air follows from the ground surface, thereby increasing the volume of soil treated.
9. Incremental installation of wells, although probably more expensive, allows for a greater degree of freedom in design. Modular construction where the most contaminated zones are vented first is preferable.
10. Use of soil vapor probes in conjunction with soil borings to assess final clean up is less expensive than use of soil borings alone. Usually a complete materials balance on a given site is impossible because most sites have an unknown amount of VOC in the soil and in the groundwater.
11. Soil vapor extraction systems are usually only part of a site remediation system.
12. Although a number of variables intuitively affect the rate of chemical extraction, no extensive study to correlate variables to extraction rates has been identified.

Neil J. Hutzler, Blane E. Murphy, and John S. Gierke are with Michigan Technological University, Houghton, MI 49931.

***Paul R. de Percin** is the EPA Project Officer (see below).*

The complete report, entitled "State of Technology Review: Soil Vapor Extraction Systems," (Order No. PB 89-195 184/AS; Cost: $15.95, subject to change) will be available only from:

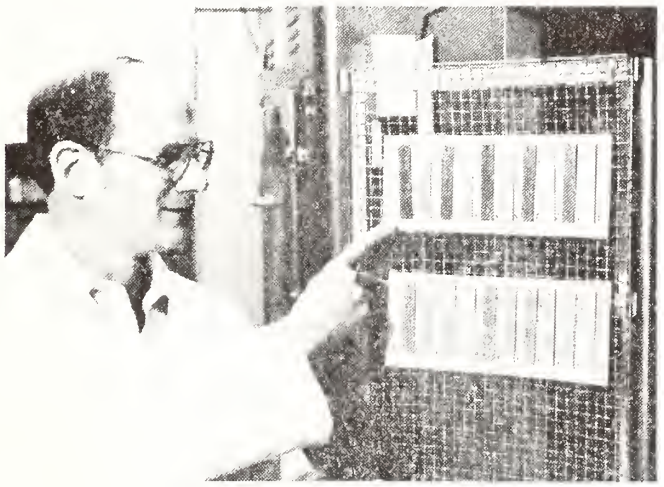
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Risk Reduction Engineering Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Effects of Acidic Rain on Wood and Painted Wood

Acidic rain (which can include snow, fog, and other atmospheric deposition) and/or its precursors are suspected of causing more rapid deterioration or weathering of many materials. Researchers at the Forest Products Laboratory (FPL), in cooperation with the Atmospheric Research and Exposure Assessment Laboratory of the Environmental Protection Agency, Raleigh, North Carolina, are investigating the incremental effects of acids on the weathering of wood and painted wood. Even minor deterioration may result in considerable economic loss because of the large number of painted buildings, fences, signs, and other wood materials exposed outdoors.



The difference in the appearance of these wood specimens is caused by the acid versus nonacid treatment they received during exposure in the weathering chamber.

Researchers at FPL have found that brief exposure of wood to acid during accelerated weathering increased the deterioration rate. The rate was affected by the strength and type of acid. Under conditions similar to the severest acidic condition measured outdoors, the wood surface eroded twice as fast as a similar surface that was exposed to distilled water. This more rapid weathering will shorten the service life of unpainted wood and may also affect the performance of painted wood.

The results of this research are being reported through the scientific literature and will be incorporated in documents prepared by the National Acid Precipitation Assessment Program (NAPAP) for presentation to the President and Congress. These NAPAP reports will provide the technical background for decisions regarding acid rain legislation.

For additional information, contact:
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References

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Manufacturing, Machinery & Tools

0578 Solutions to Manufacturing Problems Only a Modem Away Through BMP Database

0579 Quality in Automation Project Targets Small Companies

0580 Welding and Cutting a Nickel Alloy by Laser—The technique can be effective and energy-efficient.

Testing & Instrumentation

0581 Automatic Tension Adjuster for Flexible-Shaft Grinder—A simple pneumatic device reduces wear and increases efficiency.

0582 Filter Enhances Fluorescent-Penetrant-Inspecting Borescope—A slip-on eyepiece suppresses harmful radiation and seals out ambient light.

0583 Welding-Current Indicator—A light flashes on to indicate high current.

Other Items of Interest

0574 Robot Hand Would Adapt to Contours—A conceptual device would use hydraulic pressure to activate fingers.

Solutions to Manufacturing Problems Only a Modem Away Through BMP Database

The Best Manufacturing Practices Management Information System is a database that is a logical extension of the BMP program's goal of identifying and making available as much information as possible on the best practices of American industry in the areas of design, test, production, facilities, logistics, management, and transition planning. Information on who in industry is doing what in an outstanding manner is obtained by BMP surveys of companies.

The BMP database is a user-friendly, open database that provides ready help for American industry, government agencies, and academic institutions seeking to solve manufacturing problems. It is thoroughly cross-referenced, allowing companies that need help in solving manufacturing problems to determine if the BMP survey teams have identified a company that may have excelled in meeting the same or a similar problem. Companies outside the defense industry are welcome to use the BMP database too.

An ever-growing number of reports from the Best Manufacturing Practices program's surveys of companies are the heart of the BMP database. These reports document best practices and problems by functional areas and elements of the Critical Path Templates in DOD Manual 4245.7-M, "Transition From Development to Production."

Users of the database are not limited to inquiries structured by the templates. Title searches can be done using key words, such as "solder" or "welding"; brand names of equipment, material, or software; types of equipment, such as printed circuit boards; descriptive phrases such as "computer aided design"; or even a company's name and location.

The database is being upgraded to include information on the efforts and accomplishments of the Centers of Excellence which have been established or funded by the Navy Manufacturing Technology Program. This will include applied research conducted at the Electronics Manufacturing Productivity Facility, Ridgecrest, CA, involving processes and materials used in the manufacture of circuit card assemblies; research in metalworking processes conducted by the Center of Excellence in Metalworking Technology, Johnstown, PA; and research in the machining processes within a heterogeneous Computer Integrated Manufacturing environment at the Automated Manufacturing Research Facility of the National Institute of Standards and Technology, Gaithersburg, MD. Similar information on composite materials manufacturing will be provided once that Center of Excellence is established and operating.

In addition to information about manufacturing practices and problems derived from surveys, the database provides a calendar of events, listing of publications of interest, Manufacturing Technology (MT) program information, listings of key BMP and MT personnel, and contacts at companies that have been surveyed so that users can obtain more detailed information.

The BMP database was established by the Navy in 1985. It is operated by the Naval Industrial Resources Support Activity in Philadelphia.

A 300-, 1200,- or 2400-Baud modem, and a call to NAVIRSA at (215) 897-6684 during normal East Coast business hours for a user authorization, are all that are needed to access the database.

Complete information on other fea-

tures is available from the database itself or from the "BMP Management Information System Users Manual" which can be obtained by calling (202) 692-1146.

For Additional Information:

For more information about the BMP program, please contact:

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Navy Manufacturing Technology

Automated Manufacturing Research Facility

National Institute of Standards & Technology
Formerly the National Bureau of Standards (NBS)
U.S. Department of Commerce, Gaithersburg, MD 20899

Quality in Automation Project Targets Small Companies

AMRF researchers are developing a Quality in Automation (QIA) system based on deterministic metrology—which relies on understanding and controlling the machining process—to produce high accuracy parts on moderately accurate machines. Their objective is a quality manufacturing system that small companies can afford.

The system combines quality assurance's traditional methods of post-process inspection and statistical quality control (SQC) with automation's tools of real-time sensing, process-intermittent gauging, network communications, and numerical code generation.

The heart of the QIA project, its control architecture, has four levels; pre-process characterization, real-time sensing, process-intermittent gauging, and post-process gauging. Sensors at each level measure certain qualities of the part or manufacturing process and feed the information into a control strategy which makes adjustments to the process to keep it in control.

The architecture's pre-process characterization level, developed over the past year, combines laser interferometry and thermocouple measurements to characterize temperature-based machine tool errors. From these data, researchers are constructing geometric/thermal models of machine tool errors. These models will be housed in a quality controller (QC).

At the real-time sensing level, the system senses the temperature of the machine tool, vibrations from the cutting process, tool force, and surface roughness using ultrasonics. The temperature data, combined with the geometric/thermal models, enables a special-purpose controller to make real-time corrections to the cutting tool path during the machining process. The special-purpose-controller, called a real-time error corrector (RTEC), is currently under construction.

Visitors to the NIST Automation Open House in November saw a demonstration of the process-intermittent gauging level of the architecture. The high-speed probing of the machined part using touch probes stored in the tool carriage is performed at this level as well as tool setting and preliminary part alignment. The RTEC serves as a special interface between the touch probes and the quality controller to enable the fast probing operation at speeds of up to 100 in/min.

Traditional SQC is performed at the post-process gauging level. Parts are measured for dimension and form on a high-accuracy coordinate measuring machine, the project's "chief referee". The measurement results will be used for part certification and process diagnosis and will be accessible on a terminal known as the quality monitor (QM).

Use of such quality assurance systems which are based on in-process verification not only improves quality but also reduces the number of parts that must be reworked or scrapped. It has the potential for reducing or nearly eliminating final inspection. Although research on the QIA system is being performed on the machine tools of the AMRF, NIST researchers believe that the system's architecture and techniques can be applied to any discrete small lot size operation.

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NASA Tech Brief
National Aeronautics and
Space Administration

Welding and Cutting a Nickel Alloy by Laser

The technique can be effective and energy-efficient.

A report describes an evaluation of laser welding and cutting of Inconel* 718. The report notes that electron-beam welding processes have been developed for In-718, but they can be difficult to use on large or complex structures. Laser welding would be an attractive alternative if microfissuring can be avoided and if the method can match the low specific-energy input and low thermal distortion of electron-beam welding.

The evaluation included the following:

- Development of parameters for cutting and welding conditions;
- Welding and cutting test panels on the basis of selected parameters;
- Radiographic, metallographic, and mechanical evaluations of the test panels;
- Evaluation of damage on the weld underbead; and
- Evaluation of weld-gap tolerance and filler requirements.

The report concludes that laser welding is an effective joining method for In-718 in up to ½-in. (1.27-cm) thicknesses. It produces a high joint efficiency (welded joints retain about 90 percent of the strength of the unwelded alloy) and narrow welds having high depth-to-width ratio. It requires low specific-energy input, and thermal distortion is minimal.

To obtain autogenous welds with good bead reinforcement, it is necessary to fit together the faying surfaces within 3 percent of the thickness of the material. Components closer than 1 in. (2.54 cm) to the underbead can be severely damaged during high-power welding.

Furtner development is needed to reduce porosity defects, particularly in material one-half in. (1.27 cm) thick. More work is also needed to analyze microfissuring in restrained weldments.

Cutting of In-718 by laser is fast and produces only a narrow kerf. The cut edge requires dressing, however, if it is to endure fatigue.

*"Inconel" is a registered trademark of the INCO family of companies.

This work was done by C.M. Banas of United Technologies Corp. for **Marshall Space Flight Center**. *"Laser Welding and Cutting of In-718 Nickel Alloy."*
MFS-27208/TN

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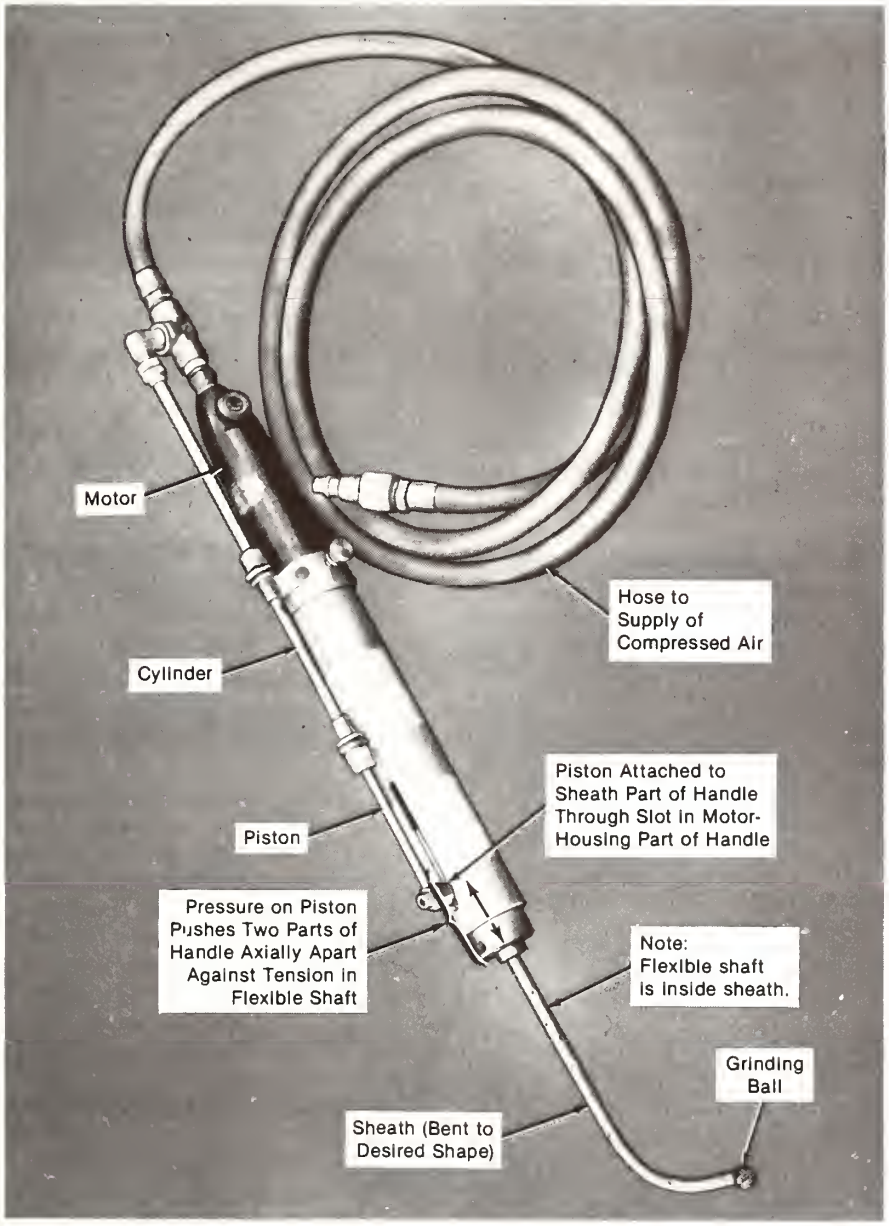
NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Automatic Tension Adjuster for Flexible-Shaft Grinder

A simple pneumatic device reduces wear and increases efficiency.


Motor
Hose to Supply of Compressed Air
Cylinder
Piston Attached to Sheath Part of Handle Through Slot in Motor-Housing Part of Handle
Piston
Pressure on Piston Pushes Two Parts of Handle Axially Apart Against Tension in Flexible Shaft
Note: Flexible shaft is inside sheath.
Grinding Ball
Sheath (Bent to Desired Shape)

An **Air Supply**, in addition to turning the motor of the tool, pressurizes a small cylinder in the handle. This puts the flexible shaft in tension, holding the grinding ball on the end of the sheath.

The flexible shaft of a grinding tool is automatically maintained in tension by air pressure. The probelike tool can be bent to reach hard-to-reach areas for grinding and polishing. Unless its shaft is held in tension, however, it rubs against its sheath, overheating and wearing out quickly. By taking up slack in the flexible cable, the tension adjuster reduces friction and enables the tool to operate more efficiently, in addition to lengthening its operating life.

For automatic maintenance of tension, a piston and cylinder are mounted on the two-part handle of the tool (see figure). Air bled from the pressurized supply for the air-driven motor of the tool pressurizes the cylinder, thereby pushing the part of the handle that holds the motor axially away from the part of the handle to which the sheath is attached. The axial separation of the two parts of the handle is restrained by the tension in the flexible shaft, which pulls the bearing surface of the grinding ball onto the end of the sheath. The tension remains constant even as the bearing surface at the end of the sheath erodes.

An orifice in the piston serves as a controlled leak to regulate the pressure on the piston. The air that flows through the orifice passes into the sheath and along the flexible shaft, thereby cooling it. The air leaves the sheath through a small hole near the outer end.

This work was done by Richard K. Burley and William S. Hoult of Rockwell International Corp. for **Marshall Space Flight Center.**
MFS-29351/TN

FOR ADDITIONAL INFORMATION: *Contact: Director, Technology Transfer Division, P.O. Box 8757, BWI Airport, MD 21240; (301) 621-0100 Ext. 241*
REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

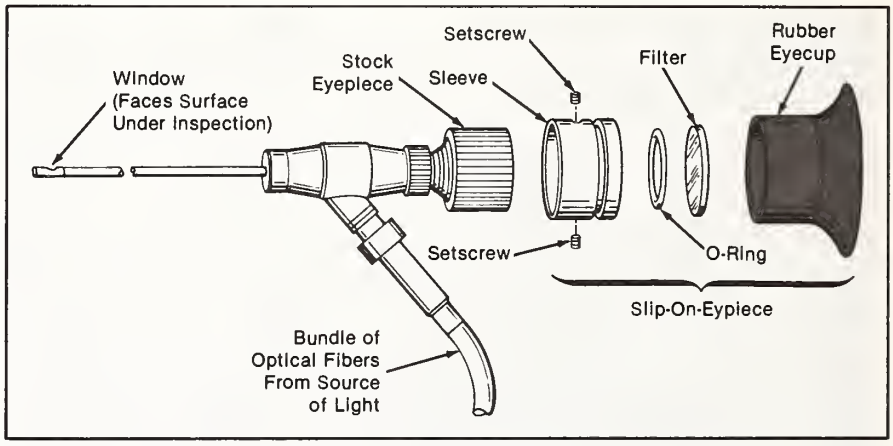
NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Filter Enhances Fluorescent-Penetrant-Inspecting Borescope

A slip-on eyepiece suppresses harmful radiation and seals out ambient light.

A slip-on eyepiece for a commercial ultraviolet-light borescope reduces both the amount of short-wave ultraviolet light that reaches the viewer's eye and the apparent intensity of unwanted reflections of white light from surfaces undergoing inspection. The eyepiece fits on the stock eyepiece of the borescope, which illuminates the surface to be inspected with intense ultraviolet light. The surface, which has been treated with a fluorescent dye, emits bright-green visible light wherever the dye has penetrated — in cracks and voids, for instance.

The light source of a borescope generates substantial amounts of undesired short-wave ultraviolet (wavelengths less than 2,000 Å) and visible light along with the desired long-wave ultraviolet light, 2,000 to 3,650 Å in wavelength, that stimulates fluorescence. The visible portion of the extra light reduces contrast so that the fluorescence is more difficult to see, and the short-wavelength ultraviolet portion is harmful to the viewer's eye. It is not practical to filter out the unwanted components at the source because the intensity of the desired long-wavelength ultraviolet would be reduced.



The **Attachment for the Borescope** contains a yellow filter.

The new eyepiece contains a deep-yellow Wratten 15(G) filter, which attenuates the unwanted light strongly but passes the yellow-green fluorescence so that defects can be seen clearly. Other filter colors were tried, including oranges, reds, and greens. Although they attenuated the short-wave ultraviolet somewhat, they adversely affected the appearance of the fluorescent light. The slip-on eyepiece is made of standard parts (see figure). It includes a rubber eyecup that shields the viewer's eye from the room light.

This work was done by Orlando G. Molina of Rockwell International Corp. for **Marshall Space Flight Center.**
MFS-29379/TN

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NASA Tech Brief
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

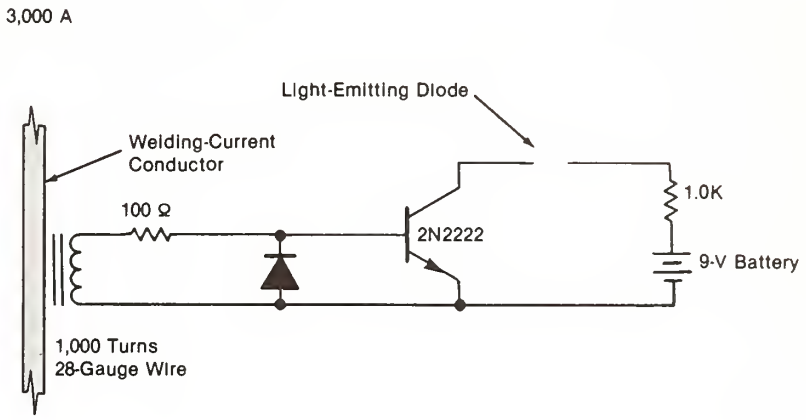
Welding-Current Indicator

A light flashes on to indicate high current.

A simple, inexpensive display circuit indicates when the 3,000-A welding current flows in a welding gun. The onset of the welding current induces a voltage and current in a 1,000-turn, 28-gauge copper-wire coil (see figure). A single-transistor amplifier amplifies the induced current, energizing a light-emitting diode (LED) connected to the collector of the transistor. Light from the LED thus gives a simple, direct indication of the welding current.

The battery-powered circuit is a low-cost, straightforward alternative to a current probe, which would require an oscilloscope to indicate that the gun is on or off. The operator would have to divide attention between the oscilloscope and the gun.

This work was done by Milton C. Hensley, Steven W. Huston, and Ralph E. Kroy of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29574/TN*



This **Simple One-Transistor Circuit** turns on a light to indicate that a 3,000-A welding current is flowing.

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Materials

0584 Bauschinger Effect In Ti-6-6-2 Alloy

0585 Corrosion Fatigue of Steel Laser Welds

0586 Solar Heat Can Transform Metals

0587 Control of Decay in Waterfront Structures

0588 Corrosion of Metals by Wood Products

0589 Hardwoods for Structural Lumber

0590 Laminated Veneer Lumber

0591 Isomeric Trisaryloxycyclotriphosphazene Polymer Precursors—These substances are useful for making heat-and fire-resistant polymers. (Licensing Opportunity)

0592 Making Fiber-Reinforced Metal by Rapid Solidification—The present role and future potential of rapid solidification are discussed.

Testing & Instrumentation

0593 Embedded Fiber Optic Displacement Sensor Conceptualized for Composites

Other Items of Interest

0577 Effects of Acidic Rain on Wood and Painted Wood

U.S. Army Fact Sheet

Bauschinger Effect In Ti-6-6-2 Alloy

Tests have been conducted at the U.S. Army Materials Technology Laboratory to determine the magnitude of the Bauschinger Effect in the Ti-6A-6V-2Sn alloy. (The Bauschinger Effect is the decrease in yield strength that results from prior plastic deformation in the opposite direction.) Specimens were prestrained varying amounts in compression, then tested in tension to determine the Bauschinger Effects. The tensile properties of the material used in this test, which contained a small amount of equiaxed alpha in a beta matrix, were:

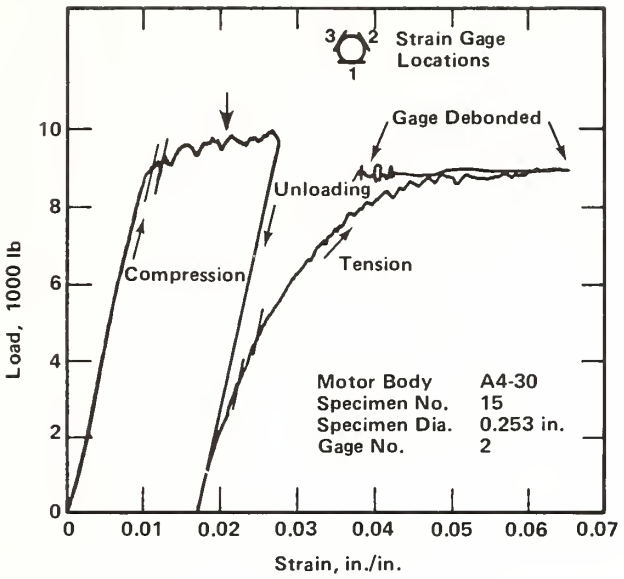


Figure . Bauschinger Effect Test

Yield strength (0.1 percent offset strain), 168 ksi
Tensile strength, 177 ksi
Elongation, 11 percent.

After about 2 percent strain in compression, the tensile yield strength was reduced to 64 ksi. Load-strain curves showing the flow behavior during both the compressive prestrain and the subsequent tensile test are shown for one of the specimens tested in Figure. · It was pointed out in this report that the stress at which yielding initiates is a significant factor in the serviceability of a component, the Bauschinger Effect may adversely affect performance. It should be noted, however, that work hardening proceeds very rapidly in reversed loaded components such that tensile strength shows little change as a result of the Bauschinger Effect.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.
NTIS order number: AD-A209355NAC
Price code: A03

Corrosion Fatigue of Steel Laser Welds

The corrosion fatigue (CF) behavior of the laser weld areas of HTS steel joined to ASTM 4140 steels has been studied at the Pennsylvania State University in research conducted for the Space and Naval War Systems Command. The components were butt welded with type 100S-1, 1.12 mm diameter filler wire using a continuous CO_2 laser beam. Compact tension specimens were machined from the weldments so that the notch exposed the base metal, the heat affected zones (HAZ), or the weld metal. Fatigue tests were conducted at 1 and 5 Hz in air and in 3.5 v/o NaCl solutions at room temperature. The 4140 HAZ and the HTS HAZ region near the weld exhibited CF crack rates in the salt water that were 6 times those obtained in air. The cracks were intergranular. The weld center region was most resistant to CF cracking with CF crack rates in salt water being below those in air.

FOR ADDITIONAL INFORMATION: A copy of the report is available from NTIS, Springfield, VA 22161; (703)487-4600.

NTIS order number: AD-A209973NAC

Price code: A03

Solar Energy Research Institute

Solar Heat Can Transform Metals

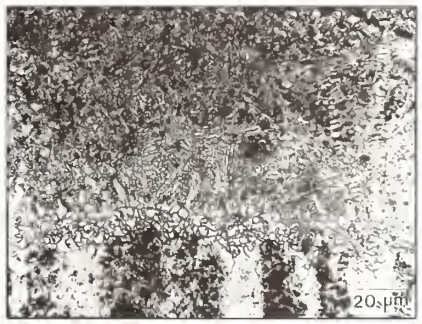
Alchemists of the Middle Ages dreamed of converting common metals to gold. SERI researchers haven't quite accomplished this feat, but they *are* developing a solar thermal process that transforms metals into more durable and corrosion-resistant substances.

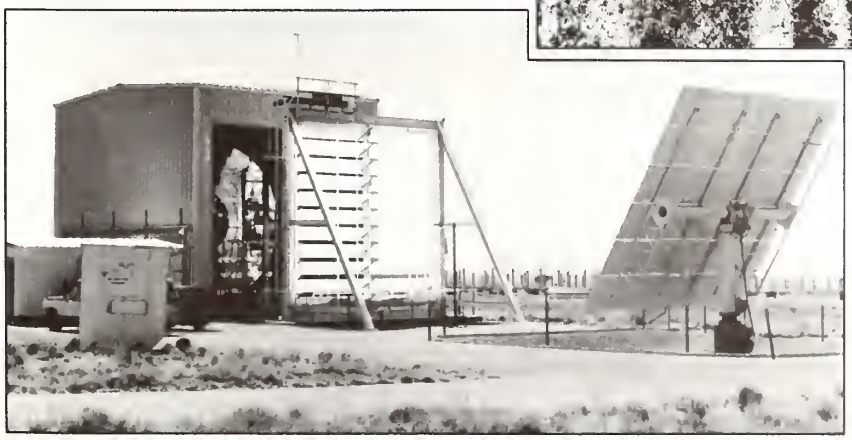
Using a 25-kW solar furnace at Sandia National Laboratories in Albuquerque, N. Mex., SERI researchers have hardened steel from 250 to almost 700 microhardness units, making it suitable for high-abrasion tools such as metal cutters and stampers. Researchers have also used the solar furnace to melt and mix a nickel-chromium powder into the top 0.5 mm of a steel test sample, creating a hard, corrosion-resistant coating ideal for turbine blades and engine parts.

Transformation occurs as an intense beam of concentrated sunlight is focused on the metal. A heliostat and a parabolic dish measuring 6.7 m in diameter can focus about 90% of the incoming radiation into a beam just a few centimeters wide. As the beam scans the metal surface, temperatures quickly reach 1000°C or more. Surface layers may undergo a phase transition, as with transformation hardening, or they can melt and mix with the substrate, as with metallurgical bonding. Rapid cooling freezes the desired phase.

Because this innovative, energy-efficient process uniformly transforms larger areas than conventional techniques, it has already attracted the attention of several companies. SERI and the Mantech Development Co. of Ft. Worth, Tex., are now investigating

Below: SERI researchers transform metals with Sandia's 25-kW solar furnace. The heliostat (right) focuses sunlight through a slatted attenuator onto a parabolic dish (inside shed), creating a narrow beam of light that can be scanned across a metal test sample. Right: Rapid heating and cooling metallurgically bonded a nickel-chromium coating (top) to steel (bottom).





the radiative joining of metals for aerospace applications. SERI has also carried out experiments for the Armco Development Company, a subsidiary of Armco Steel located in Middleton, Ohio.

Other applications may be possible, including zone melt recrystallization to create larger crystals for electronics or photovoltaics, rapid thermal annealing, and photocatalytic reactions. To better explore these possibilities, SERI plans to build a solar furnace with a secondary concentrator to yield a more intense beam. This feature should help resolve issues of penetration depth and transition zone width for better metal products.

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Refer to Volume XI, Number 3/TN

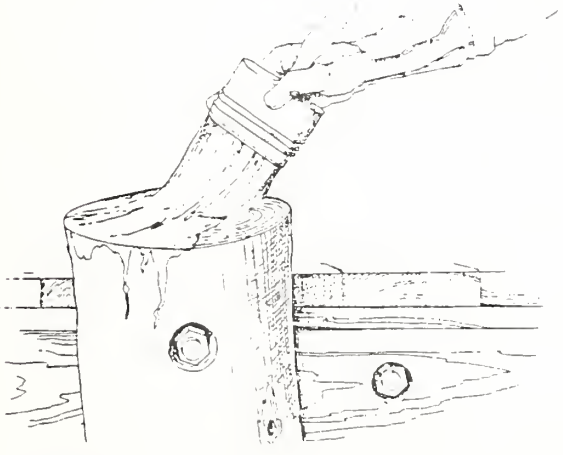
TECHLINE
Biodeterioration and Protection

Control of Decay in Waterfront Structures

Wood is one of the most widely used materials for piers and wharves. However, marina and dock owners annually lose millions of dollars because the wood in above-water marine structures was inadequately treated. Particularly prone to decay are the heartwood portions of pressure-treated Douglas-fir fender piles and other large structural timbers with deep checks that penetrate the treated shell. Premature failure is especially serious in fender piles, which protect both the docking vessel and the pier or wharf from possible impact damage.

Recent research conducted by the Forest Products Laboratory has shown that two simple in-place treatments can prevent above-water decay and extend service life of marine pilings at least 10 years.

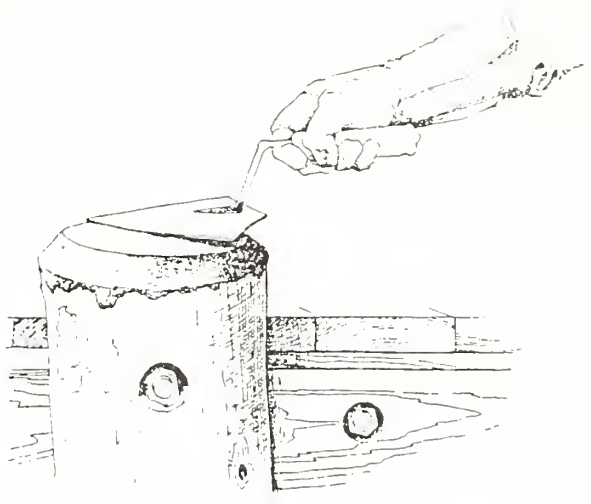
The first technique involves in-place application of either ammonium bifluoride or a fungicide in a mastic material (such as Osmoplastic (Osmose Co.) or Tritox (Koppers)) to the top surface of cut-off piles. The second technique applies a coal-tar coating "cap" on top of the treated pile.



Application of fungicide.

Douglas-fir piles achieve long-term decay protection if a 20 percent aqueous solution of ammonium bifluoride is brushed on or a fungicidal mastic is troweled on immediately after pile tops are cut off. This treatment only protects against decay starting at the top of the pile. The brush treatment with ammonium bifluoride is the easier of the two methods. Either treatment is effective by itself, and retreatment does not appear necessary for at least 10 years.

FPL researchers recommend the second step of adding a coal-tar cap to either fungicide treatment. This protective coating prevents troublesome weather checking and lengthens the inhibitive action of the fluoride treatment.



Application of coal-tar cap.

The growing replacement costs for piles, decks, curbs, fender pilings, and other waterfront structures have increased the significance of these research results. Learning to protect wood in waterfront structures is important because of wood's many unique advantages for marine use, such as high strength-to-weight ratios, resiliency, ease of construction, and relatively low cost.

The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

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This document reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Reference

Highley, T.L.; Scheffer, T.C. 1989. Controlling decay in waterfront structures. Evaluation, prevention, and remedial treatments. Res. Pap. FPL-RP-494. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 26 p.

Corrosion of Metals by Wood Products

Wood and metal are compatible in most construction and furniture uses and few corrosion problems occur. However, if there is sufficient moisture at the wood–metal interface such as around nails, spikes, screws, bolts and plates, some corrosion can be expected with metals used commonly in construction. Corrosion of the fastener often leads to deterioration of the wood and causes loss of strength to the joint and to the structural integrity of the assembly.

This corrosion is an electrochemical process. The exposed head of a nail or other metal fastener acts as the cathode and the embedded shank acts as the anode of an electrical cell. The rate and amount of corrosion depends on the metal, conductivity of the wood, temperature, and duration of the moist conditions. The risk of corrosion depends somewhat on the species, presence of external corrosive contaminants, and whether the wood has been treated with certain preservative or flame-retardant chemicals.

This nail removed from barn siding shows the corrosion possible when metal fasteners are used under moist conditions.

Most woods are slightly acidic, with a pH of 3 to 6. In some species, acid from naturally occurring acetyl groups is responsible for the low pH, but other organic acids can also cause acidic conditions. Acetic acid is volatile and is responsible for corrosion inside of closed wood containers and plastic-wrapped wooden pallets. Common metal parts stored or shipped on wood pallets covered with plastic film should be checked carefully for the possible formation of corrosion due to the volatile acids in fresh wood. Wood treated with waterborne preservatives is corrosive to some metals in moist conditions because of the copper salts in the preservative.

Scientists at the Forest Products Laboratory have studied causes and rates of corrosion in wood and preservative-treated wood. Treated wood samples containing fasteners of various metals and alloys were placed in moist exposure conditions beginning in 1973 and were periodically inspected.

For untreated wood used in damp conditions, studies found that metals resistant to corrosion should be specified and individual fasteners exposed to water should be countersunk and covered with plugs of the same species of wood. Metals hardened to Rockwell C hardness of over 30 may suffer corrosion cracking in moist wood. To prevent dissimilar metal corrosion, two different metals should not be used for fasteners. Results showed that for use with ACA- and CCA-treated wood in moist conditions, metals that are cathodic to copper in the galvanic series should be chosen.

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References

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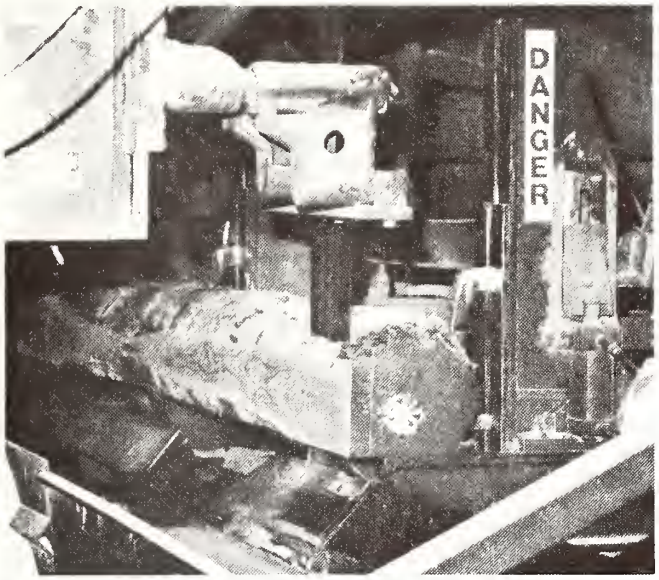
TECHLINE
Engineering Properties and Design Criteria

Hardwoods for Structural Lumber



Structural lumber produced from hardwood species may be economically competitive as lower-quality hardwoods become more abundant and research resolves technical problems.

For many years, the primary source of lumber for residential, commercial, and industrial construction has been softwood species. Hardwoods have commonly been used for higher-valued products such as furniture and cabinetry. Now, however, lower-quality hardwoods not well suited for these demanding uses are abundant. This timber resource appears suited for structural application and may be economically competitive with the softwoods in the structural lumber market.

Research has resolved many of the technical problems associated with the manufacture of dimension lumber from hardwoods, notably excessive warp and twist. (A Techline on the Saw–Dry–Rip Process is available.) Within the past 10 years, the American Lumber Standards Committee (ALSC) approved structural grading rule descriptions and allowable design stresses for four lower-density hardwood species (red alder, cottonwood, aspen, and yellow-poplar) and several higher-density hardwood species or species groups (red maple, mixed maple, beech–birch–hickory, mixed oak, red oak, northern red oak, and white oak).

Despite the removal of many technical barriers, structurally graded hardwoods are not generally available in the market. Potential producers still face uncertainties of competition with softwood lumber, pricing of hardwood lumber, and expected profit margin. These economic questions are further complicated by consumer tendency to stay with familiar products.

Despite this, the outlook for hardwood dimension lumber has never been more favorable. Increasing demand, both domestic and international, for dimension lumber and changing trade agreements with Canada are expected to severely pressure the softwood forest inventories in the United States. Research continues to remove some of the final technical barriers to hardwood use.

Mill owners must now examine all variables of economic feasibility such as log and stumpage prices, yields and product values, the costs of processing hardwoods, and capital investments for conversion of existing facilities to hardwood production or building a new mill specifically for producing hardwood dimension lumber.

The Forest Products Laboratory has just initiated research to evaluate the yield of machine stress-rated and visually graded dimension lumber from red oak logs versus alternative uses for these logs. This information will help sawmill operators select the most profitable alternative for processing hardwood logs.

For more information, contact:
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References

DeBonis, A.L.; Bendtsen, B. Alan. Design stresses for hardwood structural grades create new opportunities. In: Executive summaries from the annual FPRS meeting; 1989 June; Reno, Nevada. (Still to be published)

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Laminated Veneer Lumber

Parallel-laminated veneer panels, when ripped into lumber widths, are called laminated veneer lumber (LVL). Researched extensively at the Forest Products Laboratory (FPL) in the 1970s, this veneer processing technology combines existing plywood manufacturing methods with new laminating techniques to develop a product with greater uniformity and predictability than solid lumber. The strength of LVL specimens compares favorably with most high-strength lumber grades. As a result, LVL offers a viable alternative to structural lumber.

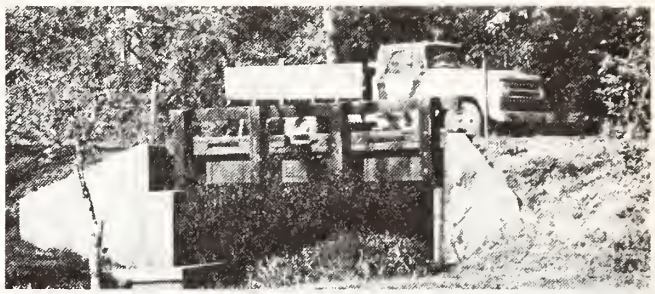
End view shows thick veneer slices are glued together to form LVL.

Most operations that produce LVL for structural use are similar to those for plywood. Veneer is rotary peeled, dried, spread with adhesive, assembled in the desired configuration, pressed (either in conventional presses or on a continuous or step basis), and ripped to width.

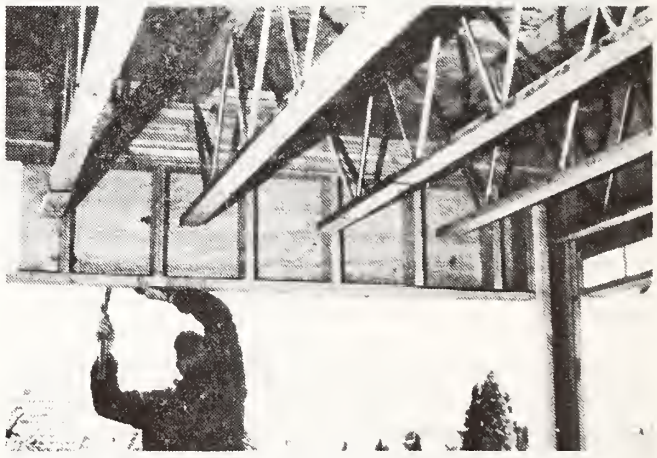
The furniture industry has used LVL for many years to produce curved furniture parts. Recently, more LVL has appeared in the marketplace as high-quality, solid-sawn structural lumber becomes more scarce and expensive. The markets for LVL appear limitless—it can be used for truss components, I-beams, bench seats, truck decking, door/window headers, scaffold planking, ladder stock, bridge stringers, and other interior and exterior applications.

Products made from LVL practically eliminate problems of warping and checking because the veneer is dried before gluing. Because laminating disperses wood defects, most mechanical properties will be more uniform than those in comparable-quality, solid-sawn wood. With the efficiency of veneer peeling, a log yields 15 to 30 percent more LVL product than solid-sawn product. In addition, preservative treatment of some species is more effective on LVL materials.

In the past 15 years, an FPL-developed database has contributed significantly to development of standards for



Exterior application—stringers and decking made of LVL were used in the construction of this bridge.



Interior application—LVL material can be used very effectively for door/window headers.

LVL products. The database focuses on raw material options, processing alternatives, product performance levels, system and product economics, and alternative marketing opportunities.

The future for this industry looks promising. The American Institute of Timber Construction provides for LVL as a substitute for tension laminates in glued-laminated beams. An American Society for Testing and Materials task group is working on a general format for evaluating structural lumber substitutes, and the American Plywood Association has proposed a standard that will use performance ratings and provide for trademarking based on the mechanical capabilities of the product.

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NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

Isomeric Trisaryloxycyclotriphosphazene Polymer Precursors

These substances are useful for making heat- and fire-resistant polymers.

One goal in the synthesis of high-performance thermoplastic polymers for adhesives and graphite-reinforced composites is to develop composites with enhanced properties, including toughness, thermal stability, and meltprocessability. Cyclotriphosphazene-based monomers and polymer precursors have led to the development of high-temperature materials. Cyclotriphosphazene-derived monomers, polymer precursors, and polymers are becoming important from both industrial and scientific points of view.

The presence of the phosphazene moiety in cyclotriphosphazene-based monomers and polymer precursors is expected to impart special properties in desired high-performance materials containing inorganic backbones for aerospace applications. The initial phase of research on these materials has been devoted to the development of various cyclotriphosphazene-derived monomers and polymer precursors, including halo-, nitro-, and amino-derivatives, which are potentially useful for making various polymers.

Efficient procedures for the synthesis of isomeric novel amine- and nitro-terminated trisaryloxycyclotriphosphazenes [especially tris(4-nitrophenoxy)tris(phenoxy)cyclotriphosphazenes and tris(4-aminophenoxy)tris(phenoxy)cyclotriphosphazenes] from hexachlorocyclotriphosphazene were developed for various reaction conditions. Chemical characterizations were performed by use of Fourier-transform infrared spectroscopy, nuclear magnetic resonance, mass spectrometry, and elemental analysis.

Tris(4-nitrophenoxy)tris(phenoxy)cyclotriphosphazenes with melting points of 111 to 112 °C and 133 to 135 °C were obtained. A process was developed to separate these compounds from the reaction products, resulting in isomers that had sharply-defined melting temperatures. The low-pressure hydrogenation of the separated nitro compounds in the presence of platinum oxide catalyst reduced the nitro groups to the corresponding tris(4-aminophenoxy)tris(phenoxy)cyclotriphosphazenes that had melting temperatures of 131 to 133 °C and 105 to 106 °C, respectively.

The substances produced are useful for obtaining heat- and fire-resistant polymers for composites, adhesives, molding powders, and coating laminates. These compounds might also be used in structures (e.g., secondary structures in aircraft), in the construction of spacecraft, and in the electronics and computer industries.

This work was done by Terry L. St. Clair and Devandra Kumar of **Langley Research Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13819/TN.

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NASA Tech Brief
National Aeronautics and
Space Administration

Making Fiber-Reinforced Metal by Rapid Solidification

The present role and future potential of rapid solidification are discussed.

A report highlights the advantages and versatility of rapid-solidification technology in the fabrication of fiber-reinforced metal-matrix composites. It discusses the present role and future potential of the technology. It includes tables that compare the rapid-solidification methods and provides an extensive list of references.

Regardless of the end product — whether a flat panel or a turbine blade — composite monotapes are the building blocks from which continuous-length, fiber-reinforced metal-matrix composites are made. Consisting of single layers of continuous fibers embedded in metal tapes, monotapes are built up and pressed together to form the part.

The report describes a variety of methods for making monotape. Common to all is rapid solidification of the liquid metal — "rapid" meaning cooling rates of 10^4 to 10^6 K/s. Among the methods are the following:

- Powder cloth,
- Foil/fiber,
- Plasma spraying, and
- Arc spraying.

All of the methods for the fabrication of fiber/metal composites described in the report maintain accurate fiber/matrix volume proportions and accurate distributions of fibers. This is a significant advantage over such conventional powder-metallurgy techniques as extrusion or infiltration of metal.

This work was done by Ronald D. Noebe of **Lewis Research Center** *and Ivan E. Locci of Case Western Reserve University. Further information may be found in NASA TM-101450 [N89-15201], Price Code: A03 "The Role of Rapid Solidification Processing in the Fabrication of Fiber Reinforced Metal Matrix Composites."*

Copies may be purchased from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14918/TN

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REFER TO THE NUMBER LISTED AT THE END OF THIS ARTICLE

Embedded Fiber Optic Displacement Sensor Conceptualized for Composites

A new monitoring technique was conceptualized and validated at the David Taylor Research Center (DTRC), Annapolis, Maryland. This technique uses embedded optical fibers as the sensors (see Figure 2). Experimental verification of the concept and optimization of the technique have shown that two-dimensional vibration can be detected using this method. Further development is required in the data acquisition system and methodology for determination of the image center with an appropriate x-y grid sensor.

Fiber-reinforced, organic-matrix composite materials exhibit the potential to improve the damping characteristics of structural components. Vibration damping measurements of materials are generally obtained using sensors that measure beam-tip displacements by determining the position of the beam cross section with time. In these

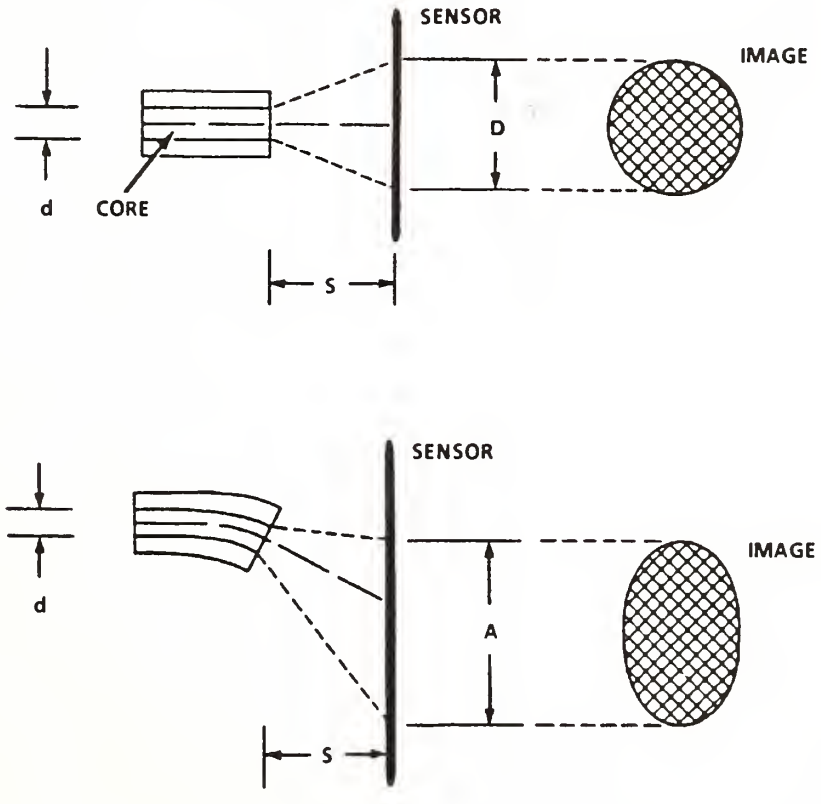

Figure 2. Schematic of the laser light exiting the embedded optical fiber

measurements, the assumption is made that the cross section moves uniformly with one-dimensional vibratory motion; i.e., the plane sections remain plane. For metals, this assumption is valid, since the material is homogeneous and isotropic. With composite materials, this is not necessarily the case, since bending-twisting couplings can occur as a result of the fiber architecture, which will result in two-dimensional vibratory motion.

For Additional Information:

Backup material on this effort is available from:

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Medicine & Biology

0594 Autoimmune Thrombocytopenic Purpura Can be Caused by a Decreased Production of Platelets

0595 Computer Graphics for Molecular Studies

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Autoimmune Thrombocytopenic Purpura Can be Caused by a Decreased Production of Platelets

Autoimmune thrombocytopenic purpura, a disease characterized by a decreased concentration of blood platelets, can be caused by a decreased production of platelets by the bone marrow as well as an increased destruction of platelets in the spleen or liver, report General Clinical Research Center investigators at the University of Washington in Seattle.

Dr. Sherrill J. Slichter (left) and Dr. Terry Gernsheimer discuss their study of blood platelet survival in patients with autoimmune thrombocytopenic purpura

Blood platelets, or thrombocytes, are small cell-like structures that are indispensable for proper coagulation, or clotting, of the blood. The researchers suggest that measurements of platelet turnover and the relative uptake of platelets by liver and spleen may help predict the success of different types of therapy.

In most previous studies investigators have concluded that low platelet counts were the result of rapid platelet destruction in the peripheral circulation. They measured platelet survival in the bloodstream by labeling platelets from a healthy individual with a radioactive isotope and then transfusing them into a patient with autoimmune thrombocytopenic purpura. The number of days these so-called homologous platelets survived was significantly shorter in patients with the disease than in healthy donors.

Principal investigator Dr. Sherrill J. Slichter, scientific director of the Puget Sound Blood Center and professor of medicine at the University of Washington School of Medicine, and her colleagues have demonstrated, however, that the earlier conclusion was based on the mistaken assumption that donor platelets would behave in the same manner as the patient's own, or autologous, platelets. In fact, the investigators have concluded that donor platelets most easily bind to the patient's antiplatelet antibodies that are characteristic of autoimmune thrombocytopenic purpura and thereby become destined for destruction.

"If one takes a population of normal donor platelets that have never before been exposed to the antibody and transfuse them into a patient with autoimmune thrombocytopenic purpura, a very susceptible population of these homologous platelets is rapidly destroyed. We obtained the wrong answer (in the past) about the predominant cause of the thrombocytopenia in this disorder not because there was anything wrong with the way we measured platelet survival, but simply because we presumed that the survival of donor platelets would be identical to autologous platelet survival. In fact, that is not the case. Donor platelets have a disproportionately much shorter survival time," Dr. Slichter says.

In many patients, ineffective platelet production by the bone marrow, rather than rapid platelet removal by the spleen and liver, is the cause of thrombocytopenia, the researchers suggest. The antibody-susceptible population of platelets in patients with autoimmune thrombocytopenic purpura never leaves the bone marrow, but are being destroyed within the marrow. The platelets that reach the peripheral circulation are apparently an antibody-resistant population that actually have a relatively normal survival.

The Seattle investigators studied the causes of thrombocytopenic purpura in 19 patients (7 men and 12 women) by counting the number of blood platelets and measuring platelet survival before and after therapy with prednisone or splenectomy, removal of the spleen, which are standard treatments for this disease. Eleven of 12 patients treated with prednisone prior to splenectomy showed a threefold average increase in platelet count, but there was no change in the rate of platelet removal from the bloodstream. According to the researchers, this finding suggests that the bone marrow in these steroid-responsive patients releases an increased number of platelets into the bloodstream.

"There is evidence that steroids interfere with macrophage removal of a variety of antibody-coated cells, and we used to postulate that steroids acted in the periphery by preventing the spleen and/or liver from taking up these platelets. Now we think steroids are affecting the bone marrow and allowing the antibody-suscept-

ible population of platelets, which never before circulated, to be released into the circulation," Dr. Slichter explains.

In contrast, 6 of 10 patients who had splenectomy had a fourfold increase in platelet count and a marked increase in platelet survival time in the bloodstream. Platelet production was unchanged in these patients. To evaluate the destruction of platelets by spleen and liver, uptake of radioactively labeled platelets by the two organs before splenectomy and by the liver after splenectomy was measured in 8 of the 10 splenectomized patients: Five in whom treatment had been successful and resulted in increased platelet concentrations and three in whom it had had no effect. The five patients in whom splenectomy was effective had lower initial liver-uptake values than two of the three patients in whom splenectomy failed and had, in addition, at least a 50-percent decrease in total platelet removal from the bloodstream after the splenectomy. There was no change in total platelet removal in two of the patients and only a 25-percent decrease in the third patient who had undergone unsuccessful splenectomy.

These results suggest that splenectomy will only be effective when the spleen is the major organ of peripheral platelet destruction. If the liver serves this function, as it appears to do in some patients with autoimmune thrombocytopenic purpura, splenectomy would not be expected to improve the platelet count, the investigators explain.

These discoveries were the product of both improved technology and good fortune. Autologous platelet survival measurements used to be carried out with platelets that were radioactively labeled with chromium-51. It was necessary for the patient to have relatively high platelet counts so enough platelets could be harvested to give a reliable measurement; that is why donor platelets were previously used for the survival studies. A new, stronger radiating isotope, indium-111, is now available, so autologous platelet survival measurements are possible in patients who are more thrombocytopenic than those in earlier studies.

"Like many things one does in science, we started out doing what we did for another reason, and then found an answer that was quite startling. Even when we started these studies we didn't make the presumption that there would be a different survival of homologous and autologous platelets. It is now obvious in retrospect, but it was not, I must admit, intuitively obvious to anybody at the time," Dr. Slichter says.

Although the pathophysiology of autoimmune thrombocytopenic purpura is becoming clearer, treatment probably will not change. The current standard therapy—steroids followed by splenectomy in patients who have become steroid-dependent—is an effective and well-tolerated regimen.

"What this study has done, I think, is change our concept of what the mechanism of the thrombocytopenia is in the first place, and then secondarily explain why patients show a response to the various kinds of therapy. So it really will do nothing to alter the way we take care of patients, but in a sense it changes our thought processes about what we are doing when we provide treatment," Dr. Slichter notes.

Jonathan Adams

At the Yerkes Regional Primate Research Center in Atlanta, Georgia, Dr. Mark E. Wilson and his associates have shown that rhesus monkeys housed outdoors mature more slowly than those housed indoors. This research may lead to a better understanding of human growth and development and to more effective treatments for growth disorders.

Photo: Regional Primate Research Center

Additional reading:

1. Gernsheimer, T., Stratton, J., Ballem, P. J., and Slichter, S. J., Mechanisms of response to treatment in autoimmune thrombocytopenic purpura. *New England Journal of Medicine* 320:974-980, 1989.
2. Ballem, P. J., Segal, G. M., Stratton, J. R., Gernsheimer, T., Adamson, J. W., and Slichter, S. J., Mechanisms of thrombocytopenic purpura: Evidence of both impaired platelet production and increased platelet clearance. *Journal of Clinical Investigation* 80:33-40, 1987.
3. Hanson, S. R. and Slichter, S. J., Platelet kinetics in patients with bone marrow hypoplasia: Evidence for a fixed platelet requirement. *Blood* 66:1105-1109, 1985.
4. Slichter, S. J., Post-transfusion purpura: Response to steroids and association with red blood cell and lymphotoxic antibodies. *British Journal of Hematology* 50:599-605, 1982.
5. Kelton, J. G., and Gibbons, S., Autoimmune platelet destruction: Idiopathic thrombocytopenic purpura. *Seminars in Thrombosis and Hemostasis* 8:83-104, 1982.

The studies described in this article were supported by the General Clinical Research Centers Program of the NIH Division of Research Resources; the National Heart, Lung, and Blood Institute; and the Department of Veterans Affairs.

For Additional Information:

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Research Resources Information Center
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(301) 984-2870

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U.S. Department of Health and Human Services Public Health Service National Institutes of Health

Computer Graphics for Molecular Studies

The Interactive Graphics Systems for Molecular Studies Resource at the University of North Carolina at Chapel Hill enables chemists and biochemists to study three-dimensional computer models of proteins and nucleic acids at various levels of detail.

Computer graphics has become an indispensable tool for studying macromolecules, the keys to life processes. Understanding macromolecules, including their three-dimensional and electronic structures, is crucial to the development of new drugs. The three-dimensional structure of proteins and nucleic acids is difficult to determine without computerized or physical models, and only computer graphics allows scientists to visualize charge distribution, electric fields, hydrophobicity and dynamic ensemble behavior.

"We work with scientists studying molecular structure to help them with difficult visualization problems," says Dr. Frederick P. Brooks, Jr., Kenan Professor of Computer Science and principal investigator on the Graphics Systems. "Our overall purpose is to make the expertise of a computer graphics group available to chemists for collaboration on chemical problems."

Built in 1974, the GRIP interactive graphics system was the first molecular graphics system with which the structure of a protein—superoxide dismutase—was elucidated without a physical model. Funded by the Biomedical Research Technology Program of the NIH Division of Research Resources, the facility was also one of the first computer-based resources to begin distributing unique software to users around the country.

The Interactive Graphics Systems Resource maintains high-performance hardware-software configurations to enable scientists to capitalize on state-of-the-art advances in computer graphics. Computer scientists at the resource center are continually developing new molec-

Mark R. Harris

Dr. Frederick P. Brooks, Jr. demonstrates the GROPE experimental force display used in drug-protein docking studies.

ular graphics software to exploit new hardware capabilities. The software is distributed to qualified users; University of North Carolina scientists help users install it and provide telephone support.

"We have several operational computer graphics systems: some systems that are standard in the industry, some homegrown systems and some experimental systems," Dr. Brooks says.

The standard systems available for distribution from the Resource include GRINCH, a system for ab initio interpretation of crystallographic maps, and RSpace, a system used by x-ray crystallographers to plan optimal data collection strategies. The experimental systems available at the Resource include GROPE, a system for studying the docking, or interaction, of drugs and enzymes or nucleic acids. In this system the chemist actually feels the forces calculated by the energy model and sees them displayed graphically, Dr. Brooks says.

"Preliminary results indicate that this helps substantially in finding favorable docking conformations [shape of molecules]," he says.

VIEW—the visualization impromptu evaluation workbench—is another experimental system available at the Resource; it is a tool for the rapid construction of many different visualizations of proteins.

Users of the graphics resource have included investigators at Duke University, who used GRINCH to study the structure of the enzyme sulfite reductase; investigators at Michigan State University, who used GRINCH to study the structure of the blood coagulation factor prothrombin fragment 1; and investigators at the Argonne National Laboratory, who used GRINCH to fit a model to an electron density map of another enzyme called delta-5-3-ketosteroid isomerase.

GRINCH and RSpace are sent to interested scientists at a charge that covers duplicating and mailing costs. The programs run on many different kinds of standard display and computer configurations. There is no charge for using the facilities at Chapel Hill.

For more information about the Interactive Graphics Systems for Molecular Studies, contact:
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Natural Resources Technology & Engineering

0596 Method for Determining the Magnitude of Earth's Gravity Developed

0597 Volcano Drilling Study Explains the Zoning of Molten Rock

0598 Calculating Irradiance for Photosynthesis in the Ocean—A mathematical model predicts the available and usable irradiances.

Method for Determining the Magnitude of Earth's Gravity Developed

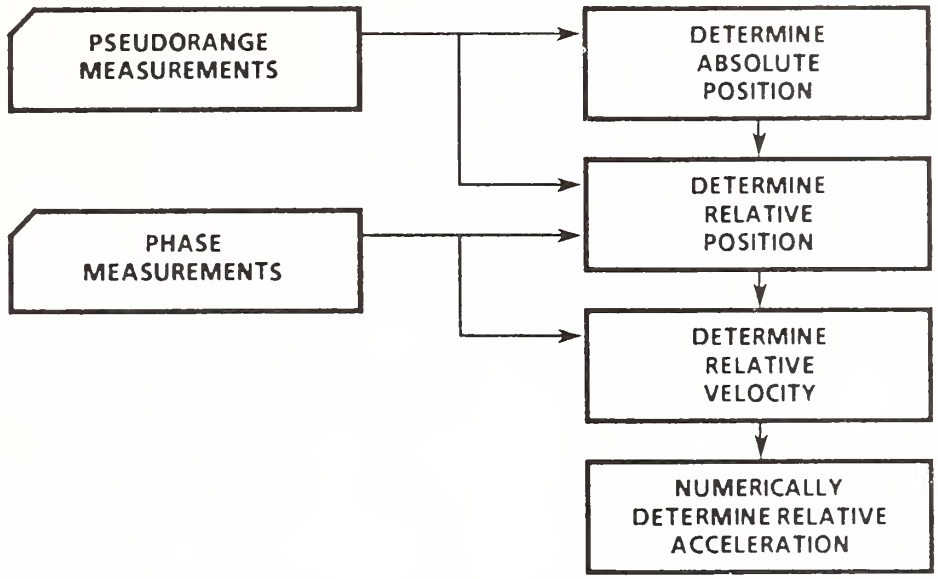

Figure 1. Flow diagram for GPS data for analysis of acceleration

NAVSTAR Global Positioning System (GPS) satellites are currently being placed in orbit to form a constellation that will enable a user to determine the position of a receiver's antenna anywhere over the Earth during all weather conditions.

This application was developed at the Naval Surface Warfare Center, Dahlgren, Virginia, and combines GPS with accurate accelerometers to determine magnitude of local gravity values (see Figure 1). Here, the accelerations due to all forces on a moving plaftorm are determined by dynamic GPS relative positioning, velocity, and acceleration techniques with respect to a fixed antenna location. The acceleration due to all forces except gravity is obtained by the accelerometers. Corrections are made for Coriolis and earth spin using GPS obtained values. The desired magnitude of the gravity vector is approximately equal to the magnitude of the vector difference between the GPS and accelerometer-determined accelerations. For a very stable vehicle platform, such as a balloon, differencing the vertical component is sufficient. This gravity determination procedure can be used for balloon or aircraft vehicles flying over rugged or inaccessible terrain. Also, aircraft have the potential to perform rapid, less expensive gravity surveys that may be used, for example, by the oil exploration industry.

For Additional Information:

Backup material on this effort is available from:

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Department of Energy

Technology Application

Sandia National Laboratory

Volcano Drilling Study Explains the Zoning of Molten Rock

A process known to pipeliners and fluid engineers has been found to operate in volcanos. Scientists at Sandia National Laboratories believe the process explains the distinct zoning of molten rock products in some volcanic eruptions.

In this "dual-liquid flow" process, liquids of differing composition separate, leaving the thicker (high-viscosity) fluid in the center of a pipe or conduit and the thinner (low-viscosity) fluid along the wall.

In response to the minimum energy principle—so called because the effect minimizes the energy needed for a given flow rate—fluids tend to separate by viscosity as the result of frictional forces along the walls of the conduit. This creates a flow system is which lower viscosity fluids surround higher viscosity fluids and lubricate their passage. In some oil pipeline applications of this idea, water has been added to help reduce the pressure needed to achieve desired flow rates.

New insight about igneous rock

Sandia geologist John C. Eichelberger and Charles R. Carrigan, a hydrodynamicist now with Lawrence Livermore National Laboratory, were the first to apply the principle to magma processes. Their work, published in *Nature* (January 18, 1990), offers new insight in explaining the distribution and composition of igneous (formerly molten) rock types on and near the surface.

"It offers an alternative to views that zoning or layering in igneous rocks simply reflects layering of the magma source," said Eichelberger, acting supervisor of Sandia's Geochemistry Division.

In the past 20 years, geologists have focused attention on the zonation of large-scale eruption products. Tuff sheets—widespread accumulations of volcanic material originally ejected into the air—appear to be deposited in an ordered fashion, ranging from high-silica content at the first-erupted bottom of the sheet to low silica at the top. This order is often interpreted to suggest that the magma sources for these deposits are also zones—with high-silica magma atop low-silica magma.

On a smaller scale, features such as dikes and lava flows also show compositional zoning. These features are "at least as dramatic, but do not suggest an obvious interpretation in terms of source layering," noted Eichelberger and Carrigan.

In fact, these lava flows are zoned in a manner that is opposite from what is expected for a layered magma source. Some geologists have suggested that the source of the flows is layered, but that the different magmas erupted in separate pulses. In this explanation, the low-silica magma "leaps ahead" of the high-silica magma to erupt first and end up on the bottom of a lava flow.

The ideal case for evaluating how zoned lava flows develop came with a research drilling program at Obsidian Dome in the Inyo chain in California, led by Eichelberger. Here both the eruptive deposits and the subsurface feeder for the same volcanic event were examined.

Penetrated volcano vent

Under sponsorship of the Department of Energy's Basic Energy Sciences Office, Sandia engineers drilled a hole slanting through the flank of the volcano and penetrating the 37-meter-wide vent. Carrigan and Eichelberger's examination of the data from the Obsidian Dome test suggest that evidence for simultaneous ejection of magmas with a range of silica contents is compelling.

Furthermore, the pattern in the conduit—a thin ring of low-silica (low-viscosity) magma surrounding a thick, high-silica (high-viscosity) core—was just what is expected for two fluids segregated by viscosity as they flow in a pipe.

Many other lava flows and exposed volcanic conduits show the same pattern. Drilling has allowed geologists to look at the lava and volcanic plumbing at the same time.

This suggests a "fundamental fluid mechanical process may be in operation," for all of these volcanos, the two researchers wrote in their article for *Nature*. The process may help to separate different magmas from magma bodies that are originally disordered rather than neatly layered.

FOR ADDITIONAL INFORMATION

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Refer to announcement 25, No. 2

NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Calculating Irradiance for Photosynthesis in the Ocean

A mathematical model predicts the available and usable irradiances.

A mathematical model yields estimates of the irradiance available for photosynthesis (E_{par}) and the irradiance usable for photosynthesis (E_{pur}) as functions of depth in the ocean. These irradiances are useful in studies of the photosynthetic productivity of phytoplankton in the euphotic layer. The model describes E_{pur} and E_{par} in terms of spectral parameters that can be measured remotely (from satellites or airplanes).

The ocean is irradiated with a solar spectrum modified by atmospheric conditions and the position of the Sun in the sky, all of which can be accounted for by detailed calculations or treated by simplifying assumptions. Assuming that the water is well mixed in the surface layer, the concentration of light-absorbing and light-scattering pigments and detritus is treated as constant with depth (see figure) and equal to the value derived from remote measurements of the optical properties of the ocean. The coefficient of spectral diffuse attenuation, $K(\lambda)$ (where λ = wavelength), is calculated from previously-developed empirical models of the light-absorbing and light-scattering properties of the pigments and detritus. Then using the spectral irradiance $E_d(\lambda, 0^+)$ just above the surface of the water, one can calculate the total spectral irradiance $E_0(\lambda, Z)$ as a function of depth Z from

$$E_0(\lambda, Z) = E_0(\lambda, 0^-)e^{-K(\lambda)Z}$$

where $E_0(\lambda, 0^-)/E_d(\lambda, 0^+)$ is the ratio of light transmitted across the sea surface.

Next, E_{par} is defined as the integral of the spectral irradiance over the visible spectrum:

$$E_{par}(Z) = \int_{400\text{ nm}}^{700\text{ nm}} E_0(\lambda, Z)d\lambda$$

This leads to the definition of a coefficient of diffuse attenuation for E_{par}, namely

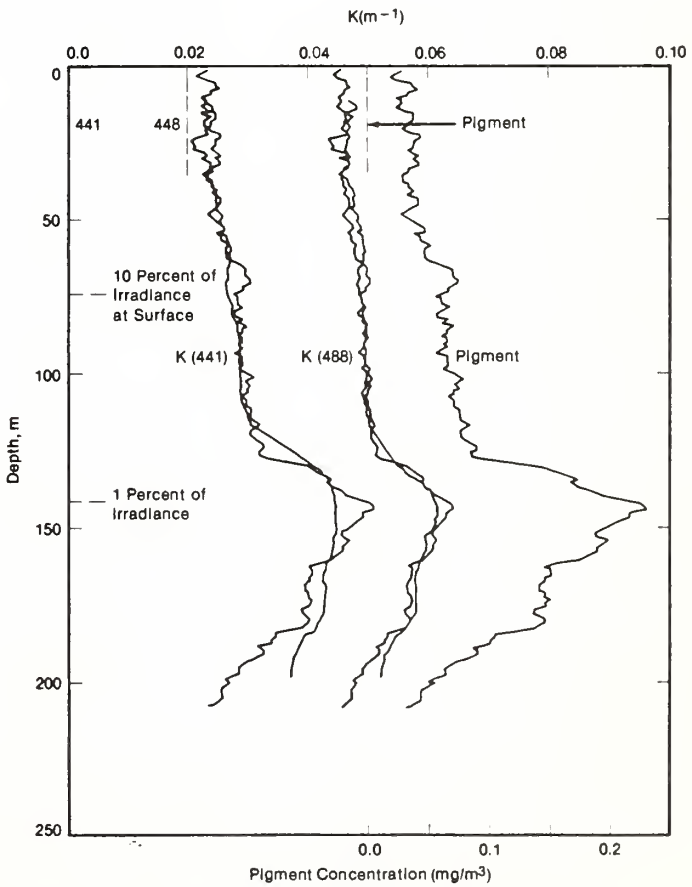
$$K_{par}(Z) = [1/E_{par}(Z)]\frac{d}{dZ}E_{par}(Z)$$

The spectral radiant flux absorbed photosynthetically is calculated as the product of $a^\circ(\lambda)$, the spectral specific absorption of chlorophyll, and the spectral irradiance. E_{pur} is defined as the integral of this spectral flux over the visible spectrum, divided by $a^\circ(\lambda)$ at a specific wavelength:

$$E_{pur}(Z) = \int_{400\text{ nm}}^{700\text{ nm}} [a^\circ(\lambda)/a^\circ(435\text{ nm})]E_0(\lambda, Z)d\lambda$$

From the preceding equations, one can also calculate other quantities useful in studies of the light field and photosynthesis. These include $K_{par}(Z)$, and $K_{pur}(Z)$, the coefficients of diffuse attenuation for $E_{par}(Z)$ and $E_{pur}(Z)$, respectively; $^*a^\circ(Z)$, the coefficient of specific diffuse absorption of chlorophyll as a function of depth, obtained by integrating the spectrally-weighted specific spectral absorption of chlorophyll over all visible wavelengths; and the radiant-energy flux absorbed by phytoplankton as a function of depth.

This work was done by Donald J. Collins and Curtiss O. Davis of Caltech, C. Rockwell Booth of Biospherical Instruments, Inc., and Dale A. Kiefer and Casson Stallings of USC for **NASA's Jet Propulsion Laboratory**.
NPO-17645/TN



The **Concentration of Pigment** is assumed to be constant with depth for purposes of the model. As these measurements from the tropical Pacific Ocean show, the concentration varies somewhat, but the assumption can be invoked because most of the light is absorbed at depths above where the concentration begins to depart sharply from the nearly constant value of about 0.03 mg/m³.

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Physical Sciences

0599 Ability to Predict Behavior of Atoms on Surfaces Improved

0600 Using Exabyte Helical Scan Devices for Data Recording

0601 NIST Announces New Radiochromic Dye Standard

0602 Acoustophoresis - A New Separation Concept—Ultrasound separates chemical species. (Licensing Opportunity)

0603 Wide-Field, Two-Stage Optical System—Wide-field, triple-Schmidt optics correct errors in large primary mirror.

0604 Ballistic-Electron-Emission Microscope—Buried interfaces are investigated with high spatial resolution. (Licensing Opportunity)

Sandia National Laboratory

Ability to Predict Behavior of Atoms on Surfaces Improved

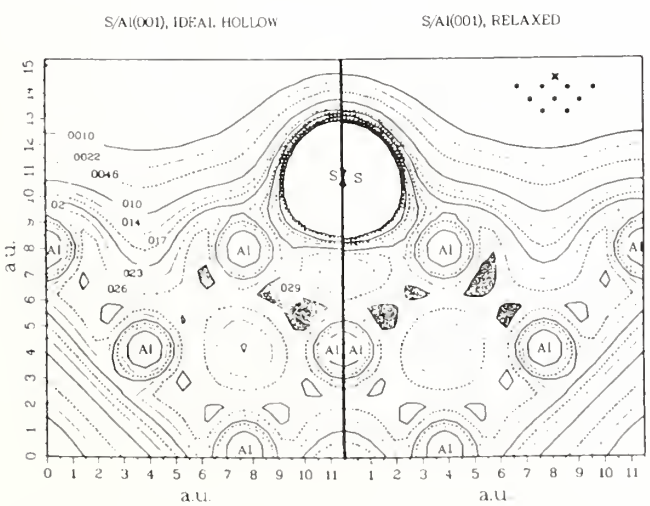
Physicist Peter J. Feibelman of Sandia National Laboratories has reported a new method of calculating how atoms and molecules interact when they are attached to metal surfaces. This research work is believed to be of considerable potential importance to the future development of "designer catalysts" used in applications ranging from auto exhaust control devices to petrochemical processing.

Feibelman reported the development at the 36th National Symposium of the American Vacuum Society, October 23-27, in Boston.

"This subject area has vast technological implications," says Feibelman. "Molecular interactions on surfaces determine the efficiency of catalytic conversion of noxious gases in auto exhaust to acceptable ones and of catalytic synthesis of petrochemicals. They are also the key to corrosion inhibition and to hydrogen uptake by metals; to adhesive properties; and to the reduction of friction."

Avoids mathematical assumptions

The new calculation method differs from previous approaches since it does away with mathematical assumptions, such as assuming that a metal surface acts in the same way as a very small cluster of metal atoms. "These were thought to be necessary to obtain numerical results, but in fact are not," says Feibelman. "Since these artifices distort the nature of the results in a way that is difficult to control, the new method represents an important improvement in our ability to predict the behavior of atoms on surfaces."



Charge density contours for a sulfur atom on an aluminum surface in a plane through the sulfur nucleus and two of its nearest neighbor aluminum nuclei. Left panel: sulfur at its equilibrium height above a rigid aluminum surface. Right panel: sulfur and nearest neighbor aluminum allowed to relax their nuclear positions.

Temperatures at which chemical reactions occur on solid surfaces must be below the solid's melting point, corresponding to rather small energies compared to typical chemical bond strengths. Therefore, one must try to predict and explain the small energy differences that correspond to different arrangements of surface atoms.

Feibelman focused on understanding weak attractive or repulsive interactions between various pairs of atoms attached to metal surfaces, and on how this interaction is affected by disturbances in the positions of the metal's atoms. Specifically, he explained why the energy required to separate a pair of aluminum (Al) atoms attached to an Al crystal surface is so much smaller than what one would guess based on the energy required to remove an aluminum atom from the crystal itself. He also explained how it is possible that a pair of atoms attached to a metal crystal can migrate along its surface more quickly than a single atom of the same species would. He showed that, in contrast to conventional wisdom, surface impurity atoms need not be attracted to defective regions of a metal crystal. Finally, he discovered, in certain cases, what forces govern how the surface atoms move when an impurity atom is attached in the immediate vicinity.

An atom disturbs a surface only in the region immediately surrounding the site where it is attached. In the new method, one guesses how the electrons in this region are distributed, and calculates how electron motion is affected by this distribution. The result is used to improve on the guess. This process is repeated till electron distribution and motion calculations are consistent. Then the energy of the surface-plus-attached-atoms is evaluated. These steps are repeated assuming different attached-atom locations. In this way, energy versus atomic configuration is determined. The results are used to interpret surface chemical phenomena.

Calculations find discrepancies

As an example, one might expect the energy to separate a pair of aluminum atoms, attached to

("adsorbed on") an aluminum surface, to be comparable to the energy per aluminum-aluminum bond to remove an atom from an aluminum crystal. Feibelman's calculations show it to be only one-eighth as much. Similar "discrepancies" are known experimentally.

The explanation follows from the fact that each aluminum atom has only three valence electrons. Forming a bond between two aluminum atoms requires electrons that would otherwise participate in binding each aluminum atom to the surface. Consequently as the aluminum-aluminum bond forms, each individual aluminum atom's bond to the surface weakens. Conversely, the cost of rupturing the bond between two neighboring aluminum atoms is compensated by the gain associated with strengthening of each atoms' bond to the surface. When an aluminum atom is removed from a crystal the cost of breaking bonds is not compensated.

As another example, adsorbed atom pairs often diffuse more rapidly than single atoms of the same species.

To understand his theory more clearly, Feibelman calculated the energy needed to move an aluminum atom from its equilibrium site, a surface hollow, to the "pass" that separates it from the next hollow.

"I repeated the calculation assuming that a second aluminum atom resides nearby," Feibelman says. "In the latter case, the calculated height of the "pass" is 18 percent less, in qualitative agreement with experiment. This result is related to the weak interaction between adsorbed aluminum atoms. Since each aluminum atom of a pair is less strongly bonded to the surface than if it were isolated from its partner, it sits higher above the surface.

Another example concerns the conventional wisdom that a small number of impurity atoms inhibits a defect-dominated surface chemical reaction by migrating to the defects and blocking them.

"I tested the generality of this concept for a common surface poison, sulfur, and a model defect, an aluminum atom adsorbed on an aluminum surface," says Feibelman. "Surprisingly, the calculations show that aluminum and sulfur repel each other, if forced to reside in neighboring hollows."

The repulsion stems from the fact that the two adjacent adatoms compete for valence electrons from the two substrate aluminum atoms that they both have as nearest neighbors. Whether the adatoms interact attractively or repulsively is determined by how each compensates for its weakened bond to the surface. The difference between the aluminum-aluminum dimer and the aluminum-sulfur is governed by the different valences of sulfur and aluminum atoms.

As an example of the effects of disturbances of the surface atoms by adsorbed species, Feibelman considered sulfur atoms on an aluminum-sulfur surface. The aluminum surface atoms bind the sulfur by contributing electrons to an adsorption bond. Intuition suggests that this results in the weakening and lengthening of the bonds of these aluminum atoms to all their neighbors; thus, the square of neighbors to the adsorbed sulfur should expand and move out of the surface.

Calculations predict otherwise. The square of neighbors does expand, but moves slightly into the surface. The reason for this unexpected behavior is that the clean aluminum surface is under tensile stress. Relief of this stress dominates the lattice distortion that the sulfur produces.

Feibelman is a Distinguished Member of Technical Staff in Sandia's Solid State Theory Division. He is the 1989 recipient of the Davisson-Germer Prize from the American Physical Society for his pioneering work in developing the theory of electromagnetic fields at surfaces. □

FOR ADDITIONAL INFORMATION

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Refer to announcement 24, No. 10

Fermi National Accelerator Laboratory

Using Exabyte Helical Scan Devices for Data Recording

Partiele-physies experiments are evolving into an era of larger deteetors recording ever greater numbers of events. (During the next run of the Tevatron, for instanee, it is antieipated that a single typieal fixed-target experiment will write enough data to fill 6000 9-track, 6250 b.p.i. tapes, and one experiment antieipates filling 200,000 of these 9-traek tapes.) Computing eapabilities have grown along with this trend, with a eoneurrent need for a more effieient and cost-effective storage mechanism for the massive data load seen now and in the future.

Fermilab has, for some time, been exploring video recording media as a way out of the data-overload quandry. Experts in the Laboratory's Computing Division (formerly the Computing Department; see item above) have settled on Exabyte 8 mm helieal sean deviees and media as an optimum data storage tool. As noted in Fermilab-published researeh, helieal-sean recorders write very narrow traeks at an aeute angle to the edge of the tape in a diagonal pattern. This technology affords a very high rate of traeks per ineh while retaining the most desirable eharaeteristie of 9-traek tape: the ability to be read on a number of eomputers. The high linear flux density of 8 mm tape results in extremely high areal density and data-storage eapaci-ty; a single 8 mm eassette will perform the storage funetion of 10 6250 b.p.i. tapes. This inereased stor-age, and the faet that a single 8 mm tape eassette, about the size of a standard audio eassette, eosts under $7, makes 8 mm helieal sean teehnology the data-storage medium of ehoiee at Fermilab.

The deviee used at Fermilab is the Exabyte EXB-8200 CTS (eartridge tape system). This drive uses the SCSI, or small computer system interfaee, bus for eommand and data transmission.

This teehnology is seen as a natural for a eomputing system, partieularly a large system where moderately high data storage is a requirement. Fermilab's investigations into the use of this teehnology are eontinu-ing. Updates, as they oeeur, on the Lab's experienees with 8 mm helieal sean teehnology will be provided provided to interested parties.

FOR ADDITIONAL INFORMATION: Office of Researeh and Teehnology Applieations, Fermi National Aeeelerator Laboratory, P.O. Box 500, MS 208, Batavia, IL 60510; (312)840-3333. Refer to FAA-525/TN.

NIST Technology Update

National Institute of Standards & Technology

U.S. Department of Commerce, Gaithersburg, MD 20899

NIST Announces New Radiochromic Dye Standard

Standard Reference Material (SRM) 4500 is a new calibration standard for the radiation processing industry. Based on research at NIST, radiochromic dyes change color - blue in this case - when irradiated, and the color intensity increases linearly with radiation dose. They can be used for standardizing measurements of absorbed dose in many radiation processing applications, such as sterilizing medical devices, curing polymer and elastomer materials, testing electronics, and for extending the shelf-life of foods. SRM 4500 consists of a set of flame-sealed amber glass ampoules, each containing 5 milliliters of solution of a radiochromic dye. These standards are for calibrating cobalt-60 and cesium-137 sources of gamma radiation for absorbed dose in the range from 50 gray to 5 kilogray (5 - 500 kilorad).

FOR ADDITIONAL INFORMATION: SRM 4500 is available for $698 from the Office of Standard Reference Materials, Rm. 204 Bldg. 202, NIST, Gaithersburg, Md. 20899; telephone: 301/975-OSRM(6776), FAX:301/948-3730.

NASA Tech Brief
National Aeronautics and Space Administration
Langley Research Center, Hampton, Virginia

Licensing Opportunity

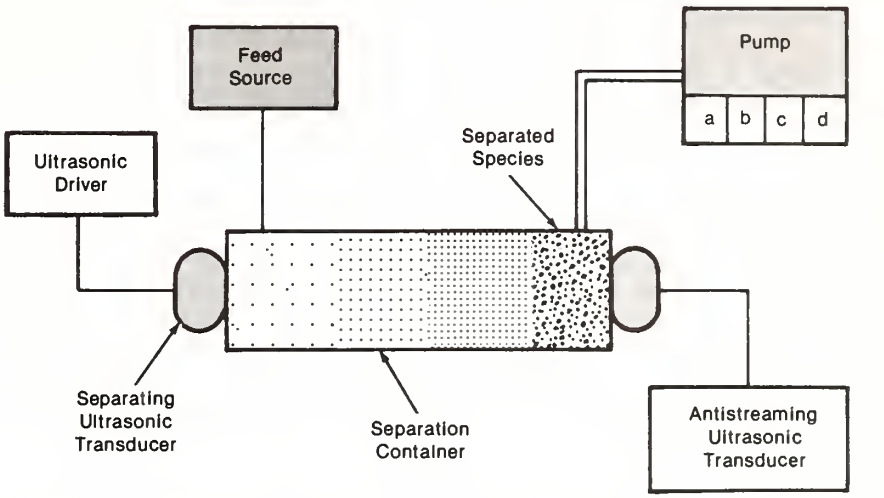
Acoustophoresis — A New Separation Concept

Ultrasound separates chemical species.

A concept under development may expand the technology of chemical separation to include ultrasonic-radiation pressure. When an ultrasonic wave passes through a medium, it carries energy and momentum: the loss of energy by the wave is accompanied by a transfer of momentum to the substance that carries the energy. For example, since molecular chains have different nonlinear properties and absorb ultrasonic energy through such mechanisms as resonance relaxation, the forces on these chains depend on the frequency of the sound. Therefore, by selecting a specific frequency, one can "tune in" to a selected chemical property — acoustic absorption — and separate chemical species (with different absorption coefficients) that may be impossible to separate by other means.

For the separation of particles, the choice of acoustic wavelength will change the acoustic scattering process and thus the force imparted to the suspended particles. As the frequency is varied from low to high, the larger particles (those with higher scattering cross section) will scatter the sound first, followed by the smaller particles. Thus, the larger suspended particles will be swept from the liquid first by the transferred momentum.

As shown in the figure, the feed source supplies the liquid medium containing the desired species in mixture with other species. The liquid is fed into the separation container. An ultrasonic transducer connected to an ultrasonic driver sends an ultrasonic wave into the liquid, exerting on the desired species an acoustic-radiation force that depends on the absorption of the acoustic wave and on nonlinear interactions. Thus, the propagation results in a separation based on the absorption (or scattering) of the acoustic wave.



The **New Technique** separates species of particles according to their ultrasonic properties.

The separated species are removed sequentially by a pump and placed in different compartments (a,b,c,d). If the absorption in the different species is nearly equal, then acoustic streaming may mix the liquid, preventing separation. To minimize that effect by counteracting the streaming, a second transducer is driven by an antistreaming device. In effect, the second acoustic wave can be tuned to a frequency different from that of the first, and to a different amplitude, thereby producing a high-resolution "shearing" of the liquid into its separate species.

The acoustophoresis concept can utilize not only bulk compressional waves but also surface waves or boundary waves between a solid (or liquid) container wall and the subject liquid. The free surface of the subject liquid acts as a waveguide that contains the input acoustic energy.

This work was done by Joseph S. Heyman of **Langley Research Center.**

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center. Refer to LAR-13388/TN.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

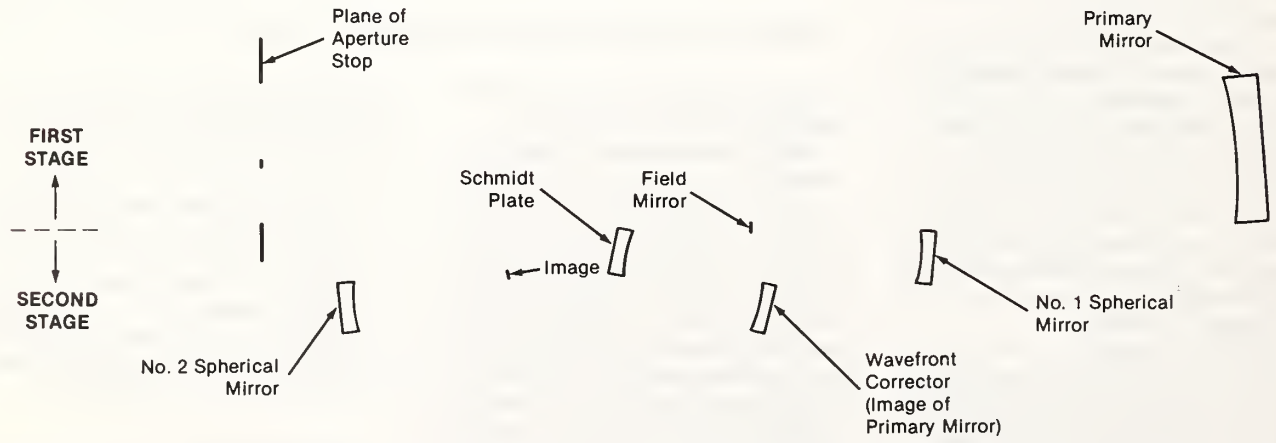
Wide-Field, Two-Stage Optical System

Wide-field, triple-Schmidt optics correct errors in large primary mirror.

A proposed telescope would offer a wide field of view, yet be relatively inexpensive to manufacture. The design, in the form of three Schmidt cameras, offers a 10-degree strip field of view, a single large-diameter collecting aperture, four spherical mirrors, and two diamond-turned aspheric mirrors in a relatively compact configuration. The uniqueness of this design (see figure) is twofold. First, the large-diameter Schmidt corrector plate, normally located at the center of curvature of the large spherical primary mirror, is relayed to a subaperture Schmidt corrector plate to be shared by all three Schmidt cameras. This reduces the number of large-diameter optics to just the primary mirror. Second, another subaperture diamond-turned corrector is located at the conjugate to the primary mirror for the purpose of removing the effects of fabrication errors on the primary mirror surface.

In a conventional telescope, a mirror of large aperture is difficult and costly to manufacture to the tolerances needed for high-acuity imaging because of its large mass and surface area. In the new telescope, the image of the large primary spherical mirror is relayed onto a smaller mirror surface, where a phase correction is applied to remove wavefront errors caused by the imperfect primary mirror. The primary mirror therefore need not be of the high quality that would otherwise be required. This concept enables cost-effective implementation of large-diameter optics by relaxing fabrication requirements. The design described is an *f*/3 triple-Schmidt with one large-diameter optic and is the first wide-field optical system to incorporate the theory of two-stage optics.

This work was done by Paul K. Manhart, Apostolis A. Deslis, Steve A. Macenka, and James B. Breckinridge of Caltech for **NASA's Jet Propulsion Laboratory**.
NPO-17392/TN



Transference of the Large-Diameter Schmidt Corrector Plate to a smaller element makes this wide-field optical system suitable for the application of the two-stage optics theory.

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NASA Tech Brief
National Aeronautics and Space Administration
NASA's Jet Propulsion Laboratory, Pasadena, California

Licensing Opportunity

Ballistic-Electron-Emission Microscope

Buried interfaces are investigated with high spatial resolution.

The ballistic-electron-emission microscope (BEEM) employs scanning tunneling-microscopy (STM) methods for the nondestructive, direct electrical investigation of buried interfaces, such as the interface between a semiconductor and a thin metal film.

With the STM system, an emitting electrode in the form of a sharp tip is held within a few angstroms of the surface of a sample and scanned piezoelectrically along the surface, while the current of electrons tunneling quantum-mechanically between the tip and the sample is measured. A computer uses the measured current as a function of position to produce a topographic image of the surface of the specimen in the form of a contour, false-color, or other map.

In the BEEM (see Figure 1), there are at least three electrodes: the emitting tip, a biasing electrode, and the collecting electrode, which receives the current that crosses the interface under investigation. A signal-processing device amplifies the electrode signals and converts them into a form usable by the computer. Like the STM, the BEEM can produce spatial images of the surface by scanning the tip; in addition, it can provide high-resolution images of the buried interface under investigation. Spectroscopic information may also be extracted by measuring the collecting-electrode current as a function of one of the interelectrode voltages.

For example, Figure 2 shows measurements taken with the tip positioned just above the surface of a gold layer deposited on negatively doped silicon. The left plot shows collector-electrode current as a function of the voltage between the base and emitter electrodes. The voltage of the transition from region A to region B is correlated with the height of the energy barrier at the interface between the gold and the silicon. The slope of region B is determined by both the thickness of the gold and the quality of the interface between the gold and the silicon. The right plot shows collector-electrode current as a function of emitter-electrode current for several values of emitter-base tunneling voltage. The plot shows the linear dependence of collector current on emitter current.

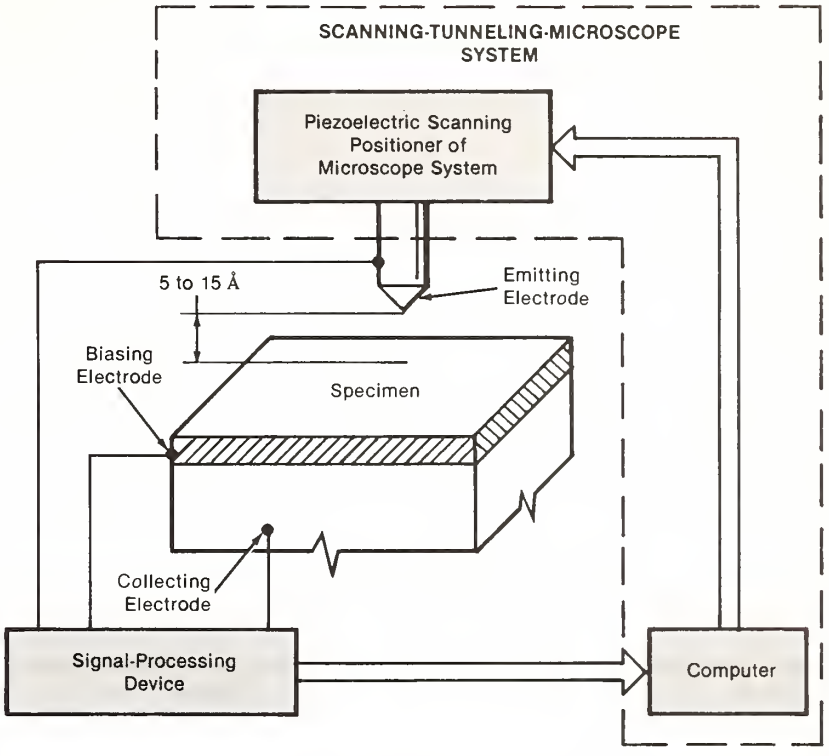

Figure 1. The **Ballistic-Electron-Emission Microscope** is a scanning tunneling microscope equipped with extra electrodes and signal-processing equipment to extract additional information about the specimen.

This work was done by William J. Kaiser and L. Douglas Bell of Caltech for **NASA's Jet Propulsion Laboratory**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-17384/TN.

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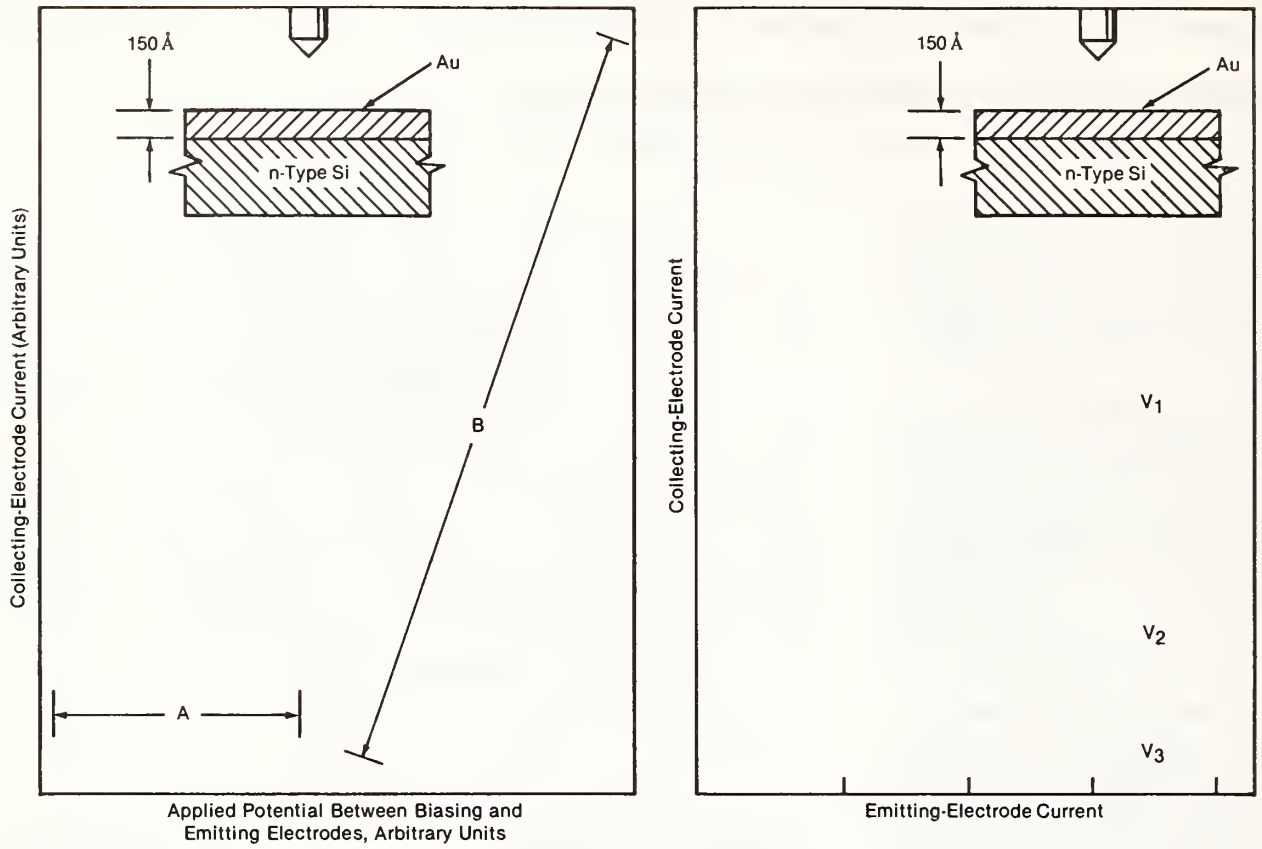

Figure 2. These **Measurements Were Taken** on a gold-silicon diode structure in an apparatus like the one shown schematically in Figure 1. These plots reveal properties of the gold layer and the gold/silicon interface.

Transportation & Components

0605 Computational Fluid Dynamics for Helicopters—Powerful computer codes are undergoing development (Licensing Opportunity)

NASA Tech Brief
National Aeronautics and Space Administration

Licensing Opportunity

Computational Fluid Dynamics for Helicopters

Powerful computer codes are undergoing development.

A report reviews the development of computational fluid dynamics (CFD) for the prediction of airflow around the rotary wings of helicopters. CFD computer codes, developed during the past 15 years, are now widely applied in industry. With them, it is now practical to make complete rotor computations, including transonic unsteady and three-dimensional effects, without resorting to empiricism and extensive libraries of data.

There is now no lack of codes, the report notes. The small-disturbance full-potential rotor code, FPR, is the simplest and most efficient. It models the essential unsteady physics and is accurate for high-Mach-number, low-lift conditions. ROT22 and TFAR1 are quasi-steady, nonconservative codes for high-lift conditions in which unsteady effects are not dominant. TFAR2, an unsteady code, has no such limitation; it produces accurate solutions to unsteady problems even though it is nonconservative.

For problems that entail very strong shocks or require detailed modeling of the near wake, it is necessary to develop codes that implement the Euler and Navier-Stokes equations of flow. New Navier-Stokes codes should eventually provide an understanding of three-dimensional stall effects. An example of this line of development is the TFAR3 code, which solves the Euler equations of transonic flow about a helicopter rotor.

The report reviews progress in the following endeavors:

- Prediction and verification of flows under various operating conditions;
- Calculation of interactions between rotor blades and vortexes;
- Analysis of viscous, transonic flows about airfoils; and
- Study of the formation of vortexes at the tips of rotors.

Computational fluid dynamics cannot yet treat realistic combinations of rotors and bodies — that is, complete rotorcraft. However, algorithms are constantly improving, and supercomputer technology is advancing at a dazzling pace. Thus, the foundation is being laid for eventual computational analysis of complete rotorcraft.

This work was done by F.X. Caradonna and W.J. McCroskey of **Ames Research Center**. *"The Development of CFD Methods for Rotor Applications."*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center. Refer to ARC-12143/TN.

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